A TREATISE

ON

EARTHQUAKE

DANGERS,

CAUSES AND PALLIATIVES,

BY

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EARTHQUAKE TOPICS;

COMPRISING

Earthquake Dynamics.
Earthquake Waves.
Sound that attends Shocks.
Lime, Mortar, etc.
Cosmogony and Seismogony.
Phenomena of the Neapolitan Earthquake of 1857.
General Observations Respecting Structural Arrangements.

"Diseased nature oftentimes breaks forth
In strange eruptions; and the teeming earth
Is with a kind of colic pinch'd and vex'd,
By the imprisoning of unruly wind
Within her womb; which, for enlargement striving,
Shakes the old beldame earth, and topples down
High tow'rs and moss-grown steeples."—[HENRY IV.

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PREFACE.

> "Our indiscretion sometimes serves us well
> When our deep plots do fail; and that should teach us
> There 's a divinity that shapes our ends,
> Rough-hew them as we may."—[SHAKSPEARE.

The preface now submitted will be chiefly occupied with apologetic explanations for total omissions, and sparseness of details, which, if elaborated at greater length, were calculated to explain many of the mysterious phenomena of earthquakes. It is doubtful, however, whether sufficient interest exists amidst the California public to have made it probable that even the cost of publication would have been realized had a work of larger pretensions and more expensive charge been submitted to its notice. Even as it is, the writer does not anticipate realizing more than cost out of pocket of printing the present *brochure*, unless, as may happen, another earthquake shock sufficiently severe as to cause general alarm should occur within a brief period, and thus again attract fresh interest to the subject.

As will be seen on a perusal of the first portions of the body of the work, the illustrations are almost wholly confined to incidents related by Mr. Mallet of the Neapolitan earthquake of 1857. It may be explained that this is attributable to the following circumstances:

The last general meeting of the Joint Committee on Earthquake Topics was held on the 11th of March last. At that meeting certain reports were read, and discussions thereon took place. The chief one, however, related to one special topic, viz: the advisability of an early publication of the information obtained by the Committee, such a course being advocated by one party as due to the public and the credit of the Committee, and another who strongly contended for an indefinite delay—one of the stoutest advocates for such delay advancing the novel plea that, individually, they had not yet learned the science of seismology, and, by inference, the cognate sciences alluded to that branch of physics. A compromise was effected by the adoption of a resolution that the Chairmen of the various sub-committees should forward at a day conveniently early and generally understood, which has now passed, reports on the various branches of this subject, on the receipt of which the Chairman was to assemble, by summons, the members of the Joint Committee. For reasons not yet explained, this has not taken place, awaiting, probably, the time when these amateur architects, chemists, geologists and general scientists, shall have, to their own satisfaction, mastered *the alphabets* of the particular sciences on which they have undertaken to treat. A portion of the resolution adopted at the same time embraced the dismissal of the Secretary, on the ground of economy.* It will be seen, therefore, that any reports which may emanate

*The above was the alleged ground of dismissal. No economy, however, inured from such a step, as is well known to many members of the Committee.

from the individuals alluded to can only be taken as personal reports—not as the results of the deliberate consultation of a Committee organized for the special purpose, unless a different course is pursued to what has taken place heretofore in the conduct of the business of the Joint Committee, and that is not likely to occur now. If the records of that Committee are searched, it will be found that only one meeting—that of a sub-committee—ever took place at which anything approaching to the semblance of a first step being taken towards the organization of a systematic investigation of any branches of the inquiry, that one being allied to the science of architecture, the results of the Committee on other subjects having been *nil*, practically, so far as the writer's knowledge extends at the moment of writing.

These explanations have been given owing to sentiments of dissatisfaction having been expressed by no inconsiderable number of members composing the Committee, some of whom, in consequence of the desultory conversational character of its meetings, eventually held aloof therefrom, and have expressed regrets that they ever allowed their names to appear amongst its list of members. At the time of dismissal, it was intimated to me that the communications and other documents accumulated during the proceedings of the Committee were its (the Committee's) sole property, and ought not to be used, excepting for its purposes. Under such a notification, I have consequently refrained from availing myself of any of the matter so obtained for the purposes of this publication. I hope shortly, however, that such documents will be open to the public generally, and, consequently, to the writer also. If this occurs, and the present *brochure* is favorably received, an opportunity will be open to me for disseminating further information on topics which have been too sparingly noticed or omitted for want of space on the present occasion; ample material existing for such a continuation of the subject, which would also be found more interesting to California readers from the circumstances of its illustrations being drawn from local sources.

To those correspondents who favored the Committee with their individual earthquake experiences, the reasons above given will, it is hoped, suffice as an apology for thus apparently overlooking their interesting communications. The time may perhaps arrive when I may be able to make ample compensation for thus subjecting them, temporarily, to the neglect of silence. It will also fall in place here to express my grateful thanks to those honorary officers of the Odd Fellows' Library who superintend its selection. Had it not been for the judicious manner in which that selection had been made, it is doubtful whether our stock of earthquake literature would have been of the scantest description. With the addition of recent arrivals, the Odd Fellows' Library is now well furnished with the most important works cognate to this subject. To the polite and gentlemanly Librarians, I wish also to publicly convey my compliments for the facilities they have always displayed when referring to the volumes under their care.

Had the wishes of the sub-committee on Finance been heeded, something of a practical character would long before this have been given to the public, for it may be added that the joint Secretaries had notified their willingness to the President of the Joint Committee to report on many matters of interest as early as January last. So far as bricks, stones, the preservation of timber, lime, mortar, etc., are concerned, the writer was as prepared to commence writing a full report thereon on the day he took office, as he is on this fifth day of May. These subjects, however new they may be to some parties, were anything but new to me.

At the commencement of this treatise it was the intention of the author to have dedicated it to the members of the Chamber of Commerce. Owing, however, to the present paradoxical position of the "Joint Committee on Earthquake Topics" with the former named body, it was conceived that any such complimentary notice might be either misinterpreted or misrepresented. It has, therefore, been deemed more fitting to omit it.

A question has often been put to the writer, and that very frequently of late, whether, in his opinion, the severest earthquake shocks felt in this city approach in severity those which have occurred and been so destructive in South America. The reports of those who were present during the earthquakes of South America last fall, are to the effect that the shocks were not sensibly more severe, but were more continuous, the shocks recurring over comparatively lengthened periods, as compared with those at San Francisco. It ought not to be overlooked in reviewing this phase of the question, that the damage that occurred at the South American cities—like that of Lisbon, in December, 1755—was largely in consequence of the earthquake wave, and the buildings destroyed were almost wholly situated on flat lying alluvium. Notwithstanding the faulty mode of building for an earthquake country adopted in the Iberian peninsula, no damage of consequence took place on that memorable occasion with such as were erected in the upper portion of Lisbon, whose foundations were on limestone. Yet it has been calculated that the great Lisbon shock was felt over more than one-fourth of the earth's surface. The great loss of life which accompanied that disastrous event was principally attributable to the falling in of arched and domed ecclesiastical buildings when densely occupied by devotees. This form of architecture is one totally unfit for a country subjected to earthquakes, unless such vaulted or dome-adorned edifices have these architectural forms constructed of iron framing. In the Kingdom of Naples, the style of building is described as presenting loftiness and thickness of walls; apertures few, but large; square-headed windows and arched doors and gateways, with heavy tiled roofs, of *low pitch*, and with deeply overhanging eaves, characterize the outside. The style of architecture, Roman, with *cinque cento*, along with later and more debased styles of ornamentation. The usually grandiose effect very generally conceals building workmanship of a very inferior quality. Materials: lava, tufa, limestone and brick, usually. Lime is abundant, but the mortar is of very slender cohesion, from too great a proportion of lime and the want of a proper quality of sharp sand.

The general style consists of a coarse, short-bedded, ill-laid rubble masonry, with great thickness of mortar joints, very thick walls, without any attention to thorough binding whatever. The opes of windows and doors often have cut limestone joints, lintels and dressings, which are but ill combined with the rest of the walls. In general, the external faces of the walls are concealed by plaster or rough cast, joists of fir timber, six to nine inches in diameter, placed at about three feet apart. Upon these joists is placed a rough planking of fir, oak or chestnut, and pegged or spiked to the beams, upon which is placed a bed of concrete or beton, six or eight inches deep. The surface is covered with a layer of red tiles, square or hexagonal, or sometimes plastered over with puzzolano mortar, painted in oil. A floor of this sort weighs from sixty to one hundred pounds to the superficial foot. The roof timbers are crossed with stout sawed laths, upon which are fixed heavy tiles of from three-fourths to one and a half inches thick. Roofing of this character is stated to weigh little less than an equal surface of the flooring noticed.

The style of building of many of the provincial towns is represented as much the same as that found in the cities, but poorer and humbler. The surface limestone, or that taken from the naturally exposed beds of rock, is commonly used to save the labor that would be required to obtain better. Hence the walls are built almost invariably of this coarse "nobby" rubble, in half-rounded blocks, or rather lumps, of stone, of nearly equal length, breadth and thickness, and resembling nothing in form more than irregular loaves of bread. The walls so constructed are almost devoid of masonry bond, and are shaken down into a heap by a shock that would only fissure a well-built and properly bonded structure.

No wonder, under such circumstances, that so many thousands of buildings were destroyed, burying thousands of the inmates in their ruins. It will be seen also from the preceding description that in Italy, as at San Francisco, a large share of the damage occasioned was attributable to an identical cause—*bad mortar*—the difference between the two cases being, that the mortar employed was of inferior cohesive and adhesive powers, owing to using too little sand and too much lime; while at San Francisco the damage was largely increased by employing mortar composed of too small a proportion of lime and too large a proportion of sand.

As I was unable to find room in the body of this treatise to insert the following, I do so here, as it serves to show that it is more economical to use lime mortar alone in place of mixing such mortar with hydraulic cement:

Mr. Ferguson, in a lecture delivered a few months ago, described good mortar as composed as follows:

COST OF CEMENT AND LIME MORTAR.		WEIGHT.
One barrel of lime, per barrel	$ 2 50	200 pounds.
Two barrels of cement at $3 50	7 00	600 pounds.
Six barrels sand at 10 cents	60	1,800 pounds.
Total	$10 00	2,600 pounds.

COST OF LIME MORTAR.		WEIGHT.
One barrel of lime	$2 50	200 pounds.
Four barrels of sand	40	1,200 pounds.
Total	$2 90	1,400 pounds.

The first would cost $7 76 per 2,000 pounds, the second, $4 14—a difference of $3 62, or more than 75 per cent.

A very mistaken view of the interest that ought to be taken in this subject exists amongst the dwellers of different parts of California. The bulk of people consider that the residents of the City of San Francisco and one or two of the more populous places, are the only parties interested in this question. What would have been the case, however, if all the country disturbed in California had been well populated, as it is anticipated to be in a very short period, and well studded with elegant mansions, substantial farm-houses and dwellings of more humble pretensions? In such a case, where would be the so exclusive interest of San Francisco and a few other cities on this subject? The Campagna of the Roman territory, with the exception of its lying on the sea-board, in place of being amongst inland waters, forms an almost exact counterpart of our swamp and overflowed lands—lands that, no doubt some day, and that not a distant one, will become the great granary and forage-producing ones of the State, and, as a natural sequence, may be expected to teem with an industrial population, requiring dwellings, farmsteads, and appropriate dwellings. Now the question how these latter ought to be built is a most important one. For more than one thousand years the Campagna was the garden of the Roman Empire. It was in the Campagna that its wealthy patricians used to retire to enjoy their "*otium cum dignitate.*" It was of the Campagna that Cato discoursed on agriculture and Virgil versified in his Georgics. The district is even now studded with the massive walls of buildings erected two thousand years ago. It became abandoned ultimately, owing almost wholly to the earthquakes which took place between the fourth and ninth centuries, political troubles at the same time contributing to this abandonment. Yet it need not have been, had residences been built suitable to have met the contingencies required in order to avoid the desolating effects of earthquakes. Owing to neglect, it has again become a miasmatic waste, the terror of travelers compelled to travel the district after nightfall.

In place of viewing earthquake phenomena with superstitious awe, surrounded by mystery, or, as some bigots would, denounce the same as curses or judgments on men's impiety, we ought, by the legitimate exercise of the mental faculties accorded to us, seek the fitting palliatives which such phenomena demand, for the purpose of obtaining security, and humbly accept them as the operations of and parts of a beneficent machinery, as seed-time and harvest.

CONTENTS.

EARTHQUAKE DYNAMICS.

CHAPTER I.

SEISMOLOGY, the Youngest Branch of Cosmical Science; Orders of Inquiry—Physical, Mathematical and Observational; Metallic Contents of Veins; Impulse; Shock; Sounds; Velocity; Elastic Wave of Shock; Evidences Fitted for Observation; Twisted or Vorticose Movements; Fractures; Relation of Velocity to Fracture; Gravity Acting with Vertical Shock; Unsymmetrical Construction of Buildings Involves Unsymmetrical Phenomena of Dissolution; Transit Velocity of the Wave Form.

"I am but the gatherer of other men's stuff, and nothing is my own but the thread that unites them."—*Kotzebue's Bouquet.*

After the explanatory remarks made in the preface, an apology is unnecessary for somewhat abruptly entering on the subject of Earthquake Dynamics, such, in fact, being the basis on which the subsequent superstructure for devising palliatives has to be formed.

It is only within the last twenty years that the phenomena associated with earthquakes have been so far studied out as to have been grouped into a separate science, which has obtained the name of *Seismology* (from the Greek word SEISMOS—an earthquake); a movement like the shaking of a sieve.

For the great advance made within the time named towards comprising many of the varied and hitherto mysterious phenomena commonly connected with earthquake exhibitions, within the bounds of exact mathematical calculations, we are indebted to the labors of Mr. Robert Mallet, Civil Engineer, F.R.S., etc.; and a large part of the present *brochure* will consist of extracts from his elaborate work, in two volumes, royal octavo, detailing what he witnessed in the Kingdom of Naples a short period after the occurrence of the earthquake of the

16th of December, 1857, which was so destructive in some of its Provinces, both to life and property. Some conception of the magnitude of the disaster may be inferred from the damage done to the dwellings situated in the towns only of one District (Sala) of the disturbed country—viz: 3,313 houses fallen, and 2,786 houses falling, and the condensed returns of killed and wounded, which numbered as follows:

PROVINCE OF BASILICATA.	KILLED.	WOUNDED
District of Potenza	9,123	1,063
District of Materna	61	42
District of Malfi	3	1
District of Lago Negro	402	237
Total	9,589	1,343

The returns just given were only those from towns and comparatively populous places; outlying solitary dwellings, farm-houses and hamlets not being included in the returns, so that it is estimated as probable that not less than 15,000 persons were either deprived of life or seriously injured at this catastrophe, thus aggregating an appalling amount of human misery effected in a few seconds;—almost the whole of which, according to Mr. Mallet, was preventable by the exercise of proper care in the selection of appropriate methods of constructing dwellings in an earthquake region—by the adoption of which latter Mr. Mallet claims that the repetition of such frightfully disastrous consequences as above stated, on the recurrence of earthquakes, might be completely avoided.

It is well remarked by Mr. Mallet, in his preface to the work just noticed, "that it is the nature of all science to be but the portal to greater and higher truths beyond. Such is peculiarly the case with Seismology. The exact knowledge of earthquakes, of their distribution in time and space, of their movements, results, and proximate causes, however interesting themselves, being but means to an end.

"As Paleontology—itself dependent upon natural history—Lithology, and many other cognate knowledges, are but instruments of Geology, so is Seismology chiefly to be viewed and valued as the instrument by which a knowledge of the deep interior of our planet will be attained—the only instrument yet discovered to this end, yet one possessed of vastly greater power and directness of aim than any of those that physical geology has previously called to its aid.

"Though the youngest branch of cosmical science, it is to be regretted that it has not been already better understood and more applied by observational geologists, many of whom, had they mastered even its rudiments, might ere now have come laden with fruit from various regions."

In the work alluded to, Mr. Mallet observes: "Were Seismology an older and more mature branch of science than it is, it would be impertinent to enter at any length into the means and methods by which it is to be pursued, by the observation of earthquake phenomena. Dating, however, for anything approaching to scientific guidance or precision not more than twelve years back,* it is the more necessary to make generally intelligible the methods of observation which can be pursued in an earthquake region after the occurrence of an earthquake shock, in order that the evidence upon which conclusions may be drawn as to the direction, velocity, amount of movement, etc., of the latter, may be accepted with their just weight; and the rather, because, as yet, it is not to all persons quite self-evident how any information whatever can be had, or conclusions drawn, as to a phenomenon so perfectly transient and momentary as an earthquake shock, by examination, at a considerable time after its occurrence, of the region over which it had passed."

Mr. Mallet justly observes: "An earthquake, like every other operation of natural forces, must be investigated by means of its phenomena or effects. Some of these are transient and momentary, and leave no trace after the shock. Such must either be observed at the time or had from testimony. But others are more or less permanent, and, from the terrible handwriting of overturned towns and buildings, may be deciphered, more or less clearly, the conditions under which the forces that overthrew them acted, the velocity with which the ground beneath was moved, the extent of its oscillations; and, ultimately, the point can be found in position, and depth beneath the earth's surface, from which the original blow was delivered which, propagated through the elastic materials of the mass above and around, constituted the shock.

Certain effects, such as landslips, fissures, alteration of water courses,

*This was written in 1858, the first article of Mr. Mallet having appeared in a paper entitled "The Dynamics of Earthquakes," published in the Transactions of the Royal Irish Academy, Vol. XXI, Part 1, about the year 1850. The late Mr. William Hopkins, Cambridge, England, communicated to the British Association, at the meeting at Oxford, 1847, a mathematical resume of the laws of gravitation, in which Mr. H. incidentally pointed out the geometric condition by which, if the emergence of a shock is known, the depth of the origin might be calculated. Mr. Mallet's method, however, differs from that of Mr. Hopkins.

etc., are also sometimes produced, of greater or less permanency, affecting the natural features of the shaken country.

The observation of each of these classes of effects bears reference to two distinct orders of earthquake inquiry.

By the first, we seek to gain information as to the depth beneath the surface of our earth at which these forces (whether volcanic or otherwise) are in action, whose throbbings are made known to us by the earthquake, and thus to make one great and reliable step towards a knowledge of the nature of these forces themselves. This is the great and hopeful aspect in which seismology must be viewed and chiefly valued. It affords, if not the only, certainly, in the existing state of knowledge, the best means, by which we can entertain a well-founded expectation of ultimately obtaining clear and certain ideas as to the material composing, and also the state, of the internal mass of our planet, thus comprehending an inquiry into the true nature, source and relations of volcanic energy.

By the second order of inquiry, we seek to determine the modifying and moulding power of earthquakes upon the surface of our world as we now find it; to trace its effects, and estimate their power and extent upon man's habitation and himself. Mr. Mallet justly claims that the first order of inquiry must be pursued by methods, chiefly mechanical, physical and mathematical. The second, by these combined with observational tact, when also accompanied by the largeness of a disciplined imagination and eye that are amongst the chief accomplishments of the physical field-geologist.

In the sentiments just quoted the writer fully concurs, and respectfully begs to add that no class of men are so deeply pecuniarily interested in this inquiry as those occupied in mining for metals amidst fissure veins. For more than twenty years the author of this *brochure* has held the opinion that the fissured or rake veins—pipes or chimneys from which the great bulk of lead, copper, antimony, silver and gold, are obtained—have resulted from the filling up of vacancies previously occasioned by earthquake agencies with those metals, their components and gangues. More on the subject hereafter.

In order to enable the reader to comprehend some of the more difficult problems associated with earthquakes, which will have to be attended to subsequently, an epitome of the axiomatic mechanical data on which Mr. Mallet has based his mathematical calculations relating thereto, will now be given. On these data the writer believes that all physicists will concur, viz: That whenever a blow or pressure of any sort is applied, or the passive force of a previously steady or slowly variable pressure is suddenly either increased or diminished, upon material substances, all of which, whether solid, liquid or gaseous, are more or less elastic; that in such cases a *pulse*, or *wave* of force, originated by any such *impulse*, becomes transferred, through the materials acted upon, in all directions, from the *origin* or *center of impulse*, or in such directions as the limits of the materials permit. The transfer of such an *elastic wave* being merely the continuous forward movement, of a change in the relative positions, a relative displacement and replacement of the integrant molecules or particles of a determinate volume affecting, in succession, the whole mass of material.

Ordinary sounds are waves of this sort in the air. The shaking of the ground felt at the passage of a neighboring railway train, quickly-driven laden coach, or heavily-loaded wagon, are examples of such waves on solid ground or rock. A sound heard by a person under water, or the shock felt by one lying near a blast exploded under water, form examples of an elastic wave in a liquid.

The velocity with which such a wave traverses, varies with different materials, and depends principally, in any given one, upon the degree of elasticity and upon the density. This *transit period* is constant for the same homogeneous material, and is irrespective of the amount or kind of original impulse;—as examples: in air its velocity is about 1140, in water about 4700, and in iron about 11.100 feet per second, all estimated in round numbers. In crystalline or pseudo-crystalline bodies, such as laminated slate or other rocks, the transient period may vary in three different directions. A great retardation of this period is produced in solids whose mass is shattered or broken, even when the fissures appear perfectly close.

If a person stands upon a line of railway near the rail, and a heavy blow is given to the iron rail at a few hundred feet distance, the party will almost *instantly* hear the wave through the medium of the iron rail;* directly afterwards he will feel another wave through the ground on which he stands; and lastly, he will afterwards hear another wave through the medium of the air; and if there existed a deep side-drain to the railway, a person immersed in the water would hear a wave of sound through the latter, the rate of transit of which would vary from each of the others—notwithstanding all these waves started from the same initial point, and at the same moment.

The size of such a wave—that is, the volume of the displaced parti-

*A remarkable instance of this will be given hereafter in describing the Neapolitan earthquake, where the narrator states that he heard the earthquake "*through his legs.*"

cles of the material set in motion at once—will depend upon the elastic limits of the given substance and upon the amount of power of the originating impulse. By the *elastic limits* in solids is meant the extent to which the particles may be relatively displaced without fracture or other permanent alteration. Thus glass, although in mechanical power much more elastic than india rubber, possesses a much smaller elastic limit—that is, fractures within confined limits—whilst india rubber is not fracturable at all.

Such elastic waves as we are usually enabled to observe, nearly all originate in impulses so comparatively small that we only feel conscious of their existence by sound or vibrations of various sorts, whose advancing forms are imperceptible to the naked eye. But when the originating impulse is very violent, and the mass of material suddenly acted upon very great, as in an earthquake, the size of the wave may become so large as to produce a perceptible undulation of the surface of the ground, often visible to the eye, by the transit of which, bodies on the earth become disturbed, fractured, or thrown down; chiefly, however, in the last case, through their own inertia.

For the reason given, it is now considered established that an earthquake consists in "*the transit of a wave or waves of elastic compression in any direction, from vertically upwards to horizontally in any azimuth, through the crust and surface of the earth, from any center of impulse, or from more than one, and which may be attended with sound and tidal waves, dependent upon the impulse and upon circumstances of position as to sea and land.*"

Mr. Mallet contends, and the writer thinks justly so, that until the above axiom was clearly grasped, the observation of earthquake phenomena, in the absence of a guiding rule, was vague and useless.

THE ELASTIC WAVE OF SHOCK.—Mr. Mallet claims that the elastic wave of shock may reach a given point upon the surface with any angle of emergence (the angle contained by the horizontal plane with the wave-path at the point of emergence), or in any azimuth. The path of the wave being deemed a right line joining that point with the center of impulse (or focus), the wave being assumed to be propagated thence in all outward directions in spherical shells. Mr. Mallet, however, candidly admits that this is only strictly true with a homogeneous elastic solid.

Mr. Mallet further asserts that every point in a coseismal line (or the line in which an earthquake-wave shall simultaneously reach the earth's surface), at the moment of shock, describes a close curve in space, returning almost exactly to the point from which it started into motion—the curve being one of double curvature, the vibration taking place nearly simultaneously in three rectangular unequal axes. For the purpose of the inquiry, however, Mr. Mallet considers that the transversal vibration may be left out of the estimate, and deems the closed curve of normal vibration as confined to vertical planes passing through the center of impulse; in fact, that the movement of the wave particles may be assumed as confined to right lines,—*in directum* with the path of the wave,—whose length is equal to its amplitude, or to one-half its complete vibration.

As the coseismal curve (or crest of a wave of shock) enlarges its area, traveling outwards in all directions from the earthquake vertical —that is, from the vertical line passing through the earth's surface (and center) and the forces—every point in and upon the surface in succession moves once forward and back, in the direction of the wave-path, and to the extent of its amplitude at that point, or in two components, vertical and horizontal, that shall give such direction.

Owing to the facts that the crust of the earth is not homogeneous, and that the focus or center of impulse is not a mathematical point, this center of impulse sometimes occupies determinate and not unfrequently wide dimensions. The angle of emergence from any given depth of focus consequently does not diminish in many cases with regularity from any given point of the surface from the earthquake vertical.

On account of the reasons just stated, neither the so-called meizoseismic curve (that of maximum earthquake overthrow), nor the isoseismic curves (or those of equal earthquake overthrow), are found to form circles, or any kind of perfectly regular closed curves, nor are the curves concentric.

With these general observations, I shall now proceed to describe the modes employed by Mr. Mallet in pursuing his earthquake inquiries.

The method of investigation which Mr. Mallet adopted is based upon the very obvious truth that the disturbances and dislocations of various solid objects by the shock of earthquake, if carefully observed with reference to their direction and extent of disturbance, and to the mechanical conditions in play, must afford the means of tracing back from their effects, the direction, velocity, and other circumstances of the movements or forces that caused them. This mode of examination,—Mr. Mallet adds,—strange to say, appears to be perfectly new,* and to have escaped the attention of all previous examiners of earthquake-shaken districts, as well as of all writers upon the subject.

*Excepting that of Mr. Wm. Hopkins, noticed in a prior note.

As illustrative of this fact, Mr. Mallet alludes to the circumstance that the Government reporter upon the great Calabrian earthquake of 1783, and, more recently, Palmieri and Scacchi reporters, upon that of Basilicata in 1851, appear to have been perfectly unconscious that in the fractured walls and overthrown objects scattered in all directions beneath their eyes, they possessed the most precise data for determining the velocities and directions of the shocks that had produced them. The idea of applying number and measure to these phenomena seems to have never occurred to them. They merely described the particulars in a loose and general way, and ordinarily as curious, remarkable or inexplicable exemplars of the power of disturbance. Hence they failed to draw a single conclusion of certainty or scientific value as to the place whence the shock emanated, how deep the wave was under the earth, or in what direction it emerged from beneath it.

Evidences Fitted for Observation.—The evidences fitted for observation after the shock, by which the conditions of earthquake motion are discoverable, Mr. Mallet considers, may be divided into two great classes:

1st. Fractures or dislocations (chiefly in the masonry of buildings) which afford two principal sources and sorts of information.

a. Information from the observed *directions of fractures or fissures* by which the *wave-path* and frequently the *angle of emergence* may be immediately inferred.

b. Information from the preceding united with known conditions as to the strength of materials to resist *fractures*, by which the *velocity* of the fracturing impulse may be calculated.

2d. The overthrow, or the projection, or both, of bodies, large or small, simple or complex, from which we may be enabled to infer—

c. By direct observation, the direction in *azimuth* of the wave-path.

d. By measurements of the horizontal and vertical distances of overthrow or of projections, to infer the *velocity* of projection and *angle of emergence*, or either of these.

Mr. Mallet claims that fractures or dislocations present themselves always in directions *more or less transverse* to the wave-path. Overthrow or projection, he contends, on the contrary, always take place *in the line* of the wave-path, or in the vertical plane passing through it; but the *direction* of fall or of projection may be the reverse (or in the contrary direction) to that of the wave transit, or it may be in the same direction with it. This will account for many of the anomalies afforded by overthrown pinnacles, etc., sometimes projected from the same buildings in directions the opposite of each other.

In accordance with the axiom thus stated, Mr. Mallet considers that at the moment of the arrival of the earth-wave at any object upon the surface whose dimensions are less than the amplitude of that wave,—an obelisk, or pillar, or single wall, for example,—motion is suddenly communicated to the body; the velocity of the vibratory particles rapidly increases from zero to its maximum, and returns to zero as it completes its *first semi-phase*, or half vibration, *the direction of movement in which it is in the same sense as that of the wave transit.*

With nearly the same rapidity the velocity increases in the opposite direction from zero to the maximum, and back to zero again. The wave has thus passed the given point, its whole phase or entire vibration having been completed, and has therefore produced its effects. The movement applied is opposed by the inertia of the body moved, whose motions and final displacement depend upon the direction of the wave-path with regard to the center of the body, its form, and the position of its base, or points of adherence or of support, and to the maximum velocity of the wave's proper motion.

The applied velocity acts at the center of gravity, and in the direction of the wave-path; and the body, if free, *apparently* moves in the *opposite direction to the wave* in its first semi-phase, in consequence of its inertia. The force of displacement, with a given maximum velocity of vibration, is therefore always proportioned to M—the mass—so that a heavy body, in the same shape and condition, is as easily upset as a light one.

If the body be not free, if the line of wave transit passing through its center of gravity pass within the base or through any other support, it does not move in the first semi-phase of the wave; but if it be free in the opposite direction, it will be displaced in the second semi-phase of the wave. But as the wave movement is now the reverse to that of its transit, the inertia of the body acting still contrary to the applied velocity, now impels the body in the *same direction* as the *wave transit.*

In either case, and in either semi-phase of the wave, the movement impressed may be one of mere overthrow or upsetting, or it may be one of actual projections, or of both combined, depending upon the special conditions of the body and its supports.

TWISTED OR SO-CALLED VORTICOSE MOVEMENTS.— Where the body is projected from the base or support with which it has had friction or adherence, and where the line of wave transit through its center of gravity does not pass also through the center of adherence—that is, the point of the base, or between it and its supports, in which all the resisting forces of adherence, etc., may be supposed concentrated—then, besides projections, a movement round a center of spontaneous rotation within the body also becomes impressed. Where this is due to adherence at the base, the rotation is generally in a vertical plane, and does not seriously disturb the plane of projection from that of the wave-path—i. e., of a vertical plane passing through earthquake focus and the body displaced—but when also due to lateral adherence, or other still more complex conditions, the body is flung forward, and whirls round an internal axis, and finally comes to rest in some position quite abnormal to its original status; giving rise occasionally to complex phenomena from which nothing can be inferred. When the body is large, such as a house or church of masonry, or even a single wall exposed to shock in the plane of its length, overthrow may be impossible with given dimensions and given angle of emergence of the wave. But in such case dislocation or fissuring occurs, and the several parts may or may not be overthrown, dependent upon the amount of the applied velocity consumed in producing fractures only.

There may be no displacement whatever of loose objects, nor any dislocation of large masses, such as churches, etc., though exposed to violent shock, if its emergence be quite or very nearly vertical, if the maximum velocity of the wave does not exceed $V = \sqrt{2\,g\,H}$—H being equal a, the amplitude of the wave—the masses in such case being rapidly lifted up and let fall again, without the withdrawal of the support of the base.

Generally, single objects situated upon the surface of the earth, in firm and rigid connection with it, or so circumstanced that the line of wave transit through the center of gravity passes through the surface of repose and of attachment, move with the earth itself, and are seldom disturbed as to their former position. Thus, also, flexible objects, rooted trees, flag-staffs, telegraph poles, and the like, are bent by the transverse forces impressed, but return to their positions, leaving only perhaps traces of the direction of movement in the earth disturbed at their bases. These observations are followed in Mr. Mallet's large work by some illustrated examples, as well as others on oscillation and effects of form.

From the examples above given, and others noticed, Mr. Mallet fairly considers he has established that the principal phenomena presented by the effect of earthquake shock upon the objects usually occurring upon the surface of the inhabited parts of the earth, resolve themselves into problems of this class, all of which are susceptible of mechanical examinations, viz:

First. Problems relating to the directions and amount of velocity producing fractures or fissures.

Second. Problems relating to the single or multiplied oscillations of bodies considered as compound pendulums.

Third. Problems relating to the theory of projectiles; in which last, the velocity being small, and the mass usually great in proportion to the range, which is also small, the problem is not disturbed by any consideration of resistance from the atmosphere.

These three classes of problems may frequently be found combined in a single example. Thus, fracture and overthrow often occur together, or fracture and projection, and sometimes all three are united; a body (a gate pier, for example,) being broken off at its base and overturned, but with a velocity more than sufficient for both, so that it is also projected or thrown to a certain distance from its base. The rule given for calculating these effects from observed earthquake phenomena, is based on the principle that the initial velocity of a body projected by earthquake shock, or that of some point in one overturned, is equal to the *maximum* velocity of the earth-wave; as upon the principle of action and re-action, the greatest effect produced will be due to the greatest applied velocity. Fractures may be considered as due to a force, $M \times V$; M being the mass of the fragment broken off, and V the velocity of its center of gravity, or of the oscillation, and equal to the maximum velocity of the wave, at the instant of passing through which the fracturing may occur.

Reference being frequently made to the direction in azimuth and emergence of the earth-wave, relative to those of walls, cardinal and ordinal buildings, or other objects affected by it, Mr. Mallet has given an explanation of these terms. Thus a rectangular building, two of whose walls run north and south, and the other two east and west, he terms a *cardinal* building; buildings whose four walls run in any other azimuth he terms *ordinal.*

Referring generally to the direction of wave transit in its horizontal component, or when nearly horizontal, as affecting cardinal buildings, which alone Mr. Mallet considers as being generally suited for observation, he denominates such wave *normal* when its azimuth is parallel to either pair of walls, viz: either north or south, or east or west.

When the line of wave transit or its horizontal component is in some intermediate azimuth, he terms the wave *abnormal.*

When a normal wave is an *emergent one* (the line of transit or wave-path inclined to the horizon), it is termed a *subnormal* wave; and in a similar case the abnormal is designated as *sub-abnormal.*

FRACTURES IN RECTANGULAR BUILDINGS AS EVIDENCES OF WAVE-PATH.—If an isolated wall (a parallelopiped) of masonry or brick, based on level ground, be subjected to the transit of an earth-wave, whose velocity is sufficient to affect the continuity of its parts, the resulting fractures, Mr. Mallet contends, will vary with the direction of the wave-path as respects the plane of the wall, and with the angle of emergence of the wave.

1st. If the wave-path be horizontal, or nearly so, *and in the plane of the wall*, the earth, in moving forward beneath the wave, tends to carry it forward by the grasp of its foundation, and at its own velocity; but this movement is opposed by the wall's inertia. The material of the wall being, within narrow limits, flexible and elastic, the tendency is to distort its figure. The phenomena under consideration could only be fully explained by means of a diagram. As the wave in the case supposed traverses beneath the entire length of the wall, the materials, by virtue of their elasticity, will oscillate in the same direction throughout the whole mass. If the wall, in consequence, becomes fissured, it will occur by a nearly vertical crack, open widest at top, and descending more or less towards the base. If the wall happens to be of absolutely uniform cohesion, there will be two such fissures, one near each end, or only one in the mid-length, dependent upon the density, cohesion, and rate of the force of transmission of its materials, and the velocity of the wave movement. Practically, such a wall is usually fissured in the weakest place.

2d. If the wave transit be horizontal, or nearly so, and *oblique to the plane of the wall*, the latter will either fall prostrate wholly, or a triangular fragment will be thrown off from the end last reached by the wave, and in the direction contrary to its transit; or the wall will be fissured only, as in the first case, dependent chiefly upon the greater or less obliquity of the line of transit to the plane of the wall. Isolated walls, exposed to oblique or to directly transverse action, may thus, when tolerably thick, sometimes be twisted considerably out of plumb without losing equilibrium or complete cohesion.

3d. If the wave emerge *with a steep angle to the horizon*, the disturbance will be that of compression in the diagonal of the wall's plane, nearest parallel to the line of wave transit; and the fissures, if they occur, will also be diagonal to the horizon, and approximate to directions perpendicular to the lines of pressure—i. e., to the line of wave transit.

If the velocity of the wave be sufficient, in relation to the density and cohesion of the wall, a triangular mass may be projected from the end at which the wave passes.

It is almost invariably found that in every building (with certain exceptions to be noticed), although the masonry, form, etc., of the building may be quite or very nearly alike at both ends, the fissures at the respective joints do not occur at equal distances from the ends measured along the side walls, nor are they equally opened, large and long, at the two opposite ends.

On this anomaly, Mr. Mallet remarks: "Whether this arises from other considerations, like those associated with the vibration of pendulous lamps set in motion by the shock, or from a real difference in velocity in the two semi-phases of the wave itself, the second semi-phase being described by a somewhat slower velocity than the first,—owing to defect of perfect elasticity in the substances composing the earth's surface,—or whether it is due to the conjoint action of the elastic wave (the earth-wave) itself, and of the wave of elastic compression of the materials of the walls themselves,—or to whatever cause which future research must make clear,—the fact he deems may be accepted as certain and very general—that the end wall, which is first acted upon by the wave (whenever it is something nearly normal), has the higher velocity shown upon it, and the fissures at that end are, *cœterie paribus*, found to be wider than those at the opposite one.

When the fractured phenomena are clear, it may always be inferred that the direction of the wave transit lies along the wave-path *towards the end that presents the widest fissures.* Mr. Mallet contends that very few large and massive cardinal buildings fissured by earthquakes will be found that will not give, as respects a normal or slightly abnormal wave, a decisive response to some one or other of its parts by this means.

Relation of Velocity and Fracture.—The force producing fracture and dislocation, caused by an earthquake shock, may be separated into two—one just sufficient to fracture the materials, the other to dislodge them more or less. Both depend upon the velocity at maximum of the wave; but the power to produce fracture depends much more upon velocity than upon the amplitude of the wave; while the energy to produce dislocation after fracture depends also upon the latter, which determines the time during which the motion of the passing wave acts upon the mass.

The flexibility and elasticity of masonry or brickwork, even of the highest quality, in masses of ordinary size, is small,—the limits of distortion without rupture, narrow; the compressive or extending forces being due to inertia, are proportional to MV, and for the same material proportionate to V only; and as the amount of extension or compression, for the unit of length due to any force *suddenly* applied to an elastic solid, is double that produced by the same force, if statically or slowly applied, the effect of a high velocity is to produce fracture with great facility, in bodies of narrow elastic limits. A wave shock of extremely small amplitude, therefore—one so small as not at all to appeal alarmingly to our senses—may yet be competent to produce considerable fracture in buildings, but in such cases the fissures will be found close and thread-like.

Direction of Fracture in Rectangular Buildings by Sub abnormal Shocks; Sub-abnormal Emergence; Finding of Trigonometrical Solution of and Geometrical Method Illustrative of Modifications; Effect of Shocks of Vertical or Nearly Vertical Emergence; Their Effects on Rectangular Buildings; Gravity Acting with Vertical Shock;—are all lengthily treated upon by Mr. Mallet. Space will not permit allusion at any great length to more than the last named subject; respecting which, he observes: With vertical or nearly vertical emergence, gravity acting with inertia, in the first semi-phase of the wave, upon the masses of masonry situated directly above the doorways, windows, and such apertures, their tendency to come down is great; and hence not only are vertical fissures formed over such openings, but they are *open widest at bottom.* Mr. Mallet remarks that: Fissures in buildings, not overthrown, are in fact the sheet anchor as respects direction of wave-path to the seismologist (earthquake observer) in the field.

It is upon the heavy Italian roofs and floors, however, that the most instant and formidable effects are produced by vertical emergence. Upon them the vertical velocity produces a momentum of inertia acting directly downwards, and therefore favored by gravity. Arched roofs, grooving, and that form of arched ceiling formed of hollow pottery, then spread the walls, as they come down, and falling upon the floors below, bring them down in succession.

The effect of want of symmetry in the several masses of masonry tends to reduce them by further dislocation, prior to complete overthrow. For example: a portion of a uniform wall, severed by transverse fissures from the remainder, but having a buttress of its own or of less hight somewhere along its length, is again transversely broken, close to the buttress, the moment of resistance to fall being different in each. The relation of the buttress to the wall, as a support against transverse forces of a statical character, is no longer the same, when the overthrow is produced by a force applied with the rapidity of the wave of the shock; there may not be time to transmit its own stability to the remainder of the wall.

When the buttress is at the same time a tower rising much beyond the hight of the remainder of the building, such arrangements generally tend to mutual destruction,—the primary fissures occurring at the junction of the two, or near them, the walls and the tower having different times of vibration, as elastic pendulums of different lengths, whether accidentally isochronous or not, produce mutual damage by their respective impulsive actions upon each other. Such action, Mr. Mallet relates, is strikingly observable with many of the meaner class of rural Italian churches, where the belfry tower is built into one of the quoins of the main rectangular building. In such, the two adjacent side-walls are frequently found, according to Mr. M., to be completely destroyed by the transverse rocking of the tower; and yet the latter may have only suffered fissuring at the lower portions, while that which rose above the level of the church walls may be completely overthrown. Such is one of the reasons which may be assigned for chimneys and fire-walls breaking off at the point where they emerge from the roof; and suggests that city blocks of buildings ought to be constructed of a uniform hight and without break in line.

Unsymmetrical Construction of Buildings Always Involves Unsymmetrical Phenomena of Dissolution.—If compelled to adopt an unsymmetrical building, for lack of a better one for observation, the first thing to be done to disentangle the phenomena, is to consider the effects due to the want of symmetry alone. If, for example, it is found that of the opposite walls of a cardinal church, one is standing, and the other prostrate, the wave transit having been abnormal, and nearly in the direction of their length, the first point to be ascertained is, was the prostrate wall symmetrical in form and structure with that remaining? Unless the offset of the roof may have overthrown the wall, it will generally be found that the fallen wall was either of much inferior masonry, or smaller thickness, out of plumb originally, or full of windows and doors, the standing wall being solid.

Such conditions, and others of a similar character too numerous to detail, are required to be known, and should be constantly sought for, by the earthquake observer, otherwise he will be liable to draw conclusions as to effects unlike, and to compare dissimilar buildings or circumstances.

TRANSIT VELOCITY OF THE WAVE FORM.—A common error appears to prevail amongst writers on physical geology and seismology, in either confounding the velocity of transit,—i. e., the rate of surface propagation of the wave of shock,—with that of the wave itself,—i. e., the rate of displacement and replacement of the particles being acted on by the wave,—or in supposing them to be necessarily the same; and a want of clearness on this point has greatly retarded the progress of earthquake investigation. A similar mistake is even found in some treatises on physical geology, in respect to the analogous cases of aqueous waves of translation, in which it is assumed that the enormous transit rate of the tidal wave of translation upon the *deep ocean* may be taken as the measure of its diluvial or drift-producing power.

The ocean tidal wave may travel across the deep Atlantic at the rate of nearly 550 miles per hour, and, on reaching soundings, be reduced at the chops of the Irish Channel to 200 or 175 miles per hour. In the channel a further reduction will take place; so that the observed rate of the tidal-stream will be found only to be two, three or four miles per hour, accompanied by a corresponding decrease in the velocity of the wave-particle itself. As the velocity is proportionate to the amplitude of the wave for a given depth, and the amplitude depends upon the depth, the analogy is with the wave of light, rather than with that of sound or shock.

Geologists must not be surprised at finding—since the velocity of transit and the velocity of the earth-wave particle at its maximum have been both measured, and for the same shock—that they differ enormously from each other; that the velocity of transit is about half that of a cannon shot; but that of the velocity of the wave particle (which does the mischief) is not as great as that with which a man reaches the ground when he jumps off a table; and yet that this small velocity is competent to produce all the violent and formidable effects of earthquake, no longer admits of doubt.

To illustrate this point, Mr. Mallet makes reference to *what should be the effect* if the velocity impressed on solid bodies by the wave were that of its transit, in the case of two balls of limestone, of one and a half feet diameter, which were projected from the campanile of Padula monastery (Certosa). If, in place of having a velocity of eleven or twelve feet per second, they had been put in motion with one of 700 or 800 feet per second, or about equal to the velocity of a 13-inch shell, on leaving the mortar, in place of falling, as they did, on the pavement forty or fifty feet from where they stood, they would have flown through the air for a mile or two.

Drawing results from the transit velocities calculated for various places, the extremes being 1,000 feet to 700 feet, afford an average transit velocity of about 850 feet; he, in consequence, calculates the velocity of shock in all parts of the world as being limited to twelve or thirteen feet per second.

Riobamba, eighty feet per second, is the greatest on record, or perhaps possible in the earth—being nearly as great as that with which the body of a person who should leap from the top of the Duke of York's column, in London, would strike the pavement; and taking the *greatest* velocity that have been ascertained for the Neapolitan earthquake at fifteen feet per second, the maximum velocity is $80 \div 15 = 5.33$ times greater than the velocity of the Neapolitan shock.

Hence Mr. Mallet concludes that the greatest possible depths of origin of any earthquake impulse occurring in our planet as limited to 5.33×34.930 feet, or to 186,176 feet, or 30.64 geographical miles, and would consequently only touch the depth which, according to the received notions as to the increment of hypogean temperature, is supposed to form the upper surface of what he terms the imaginary ocean of liquid lavas of the earth's interior.

INCIDENTS OF THE

NEAPOLITAN EARTHQUAKE

OF 1857.

CHAPTER II.

Influence of Form and Elevation on Earthquake Shocks, instanced in the cases of Castellucio; Petina; Fissures at Auletta; Pertosa; The Military Road at Campostrina, affording an Example of the Value of Good Masonry in an Earthquake Country; Terrific Effects of the Earthquake at Polla; Church of Madonna of Loretto; Atena; Diano; La Sala; The Palazzo Romani, near Padula.

> "There is some soul of goodness in things evil,
> Would men observingly distill it out."—[SHAKSPEARE.
>
> "So reads he nature, whom the lamp of truth illuminates."
> —[COWPER'S TASK, BOOK V.

In the preface it is explained that the author does not feel himself at liberty to use that information (though known to him) which he became acquainted with as Secretary to the Joint Committee on Earthquake Topics. As, however, the phenomena accompanying earthquakes are the same the world over, a good description of such occurring in Italy, forms as safe a beacon of guidance from danger, by pointing out the necessity of adopting suitable palliatives, as could be drawn from earthquake incidents occurring in our own immediate vicinity. Those who read from amusement only, will find Mr. Mallet's narrative an interesting one.

The effects of the form, elevation above its base, substance, and direction with respect to wave-path, of the collines or spurs upon which so many of these Italian towns are perched, in modifying the results of the shock upon them, were strikingly shown at Auletta, as well as at Castellucio, which he had passed, and the little village of Petina, which from a point between Auletta and Pertosa he could descry with the telescope, perched high up upon the south scarp of Monte Alburno, at least a thousand feet above him. Petina stands upon a level sort of short stumpy, buttressed spur, jutting out from the deep mountain slope, which in form is like a piece of artificial earthwork; the little town standing upon the level platform on top, with a steep scarp in front of it, the mountain rising abruptly behind, and the scarp sloping in, and getting lost in the mountain sides to the east and west of the town. The terrace on which it stands, however, is not earth, but solid limestone, being a projection of the horizontal strip of the beds of the great scarp of Alburno which dip pretty sharply to the south. It was found, however, on inquiry here, that Petina, which is just five Italian miles southwest of Auletta, and about six from Pertosa, has suffered absolutely nothing, although these latter towns were in great part prostrated.

The immunity of Castellucio from injury, arose, according to Mr. Mallet, from the *long dimension* of its well-buttressed knoll being *opposed to the line* of shock, as well as to the barrier interposed between it and any shock coming from the eastward, by the mass of vertical breccia beds to the east of the town.

The immunity of Petina has been attributed, first, to the peculiar strong form of the terrace upon which it is placed, calculated to resist any vibration in the mass itself; second, to the fact that, calculated from Auletta Bridge, there is about 1,000 feet of piled-up limestone between that point and Petina; so that any shock emergent at a steep angle, here or farther eastward, must have passed up transversely through all these successive plates of variable hardness, and run in absolute contact with each other; and so the *vis viva* of the shock might be enormously reduced before reaching the elevation of the village.

At Auletta, it was alleged to Mr. Mallet by the *gen d'armes* who arrived there within a day or two after the shock, and whose statements were confirmed by some dozens of the poor inhabitants, that large and long fissures had opened in the earth around the town, but that they had since all become closed again, and that they doubted whether they could now be seen. Mr. Mallet gave much scrutiny to these phenomena, and having got the corporal of the guard to accompany him, the former pointed out the place where he had observed one of the largest of these fissures, to the northwest of the town, situated amongst some olive grounds in deep clays. After some time occupied in searching, Mr. Mallet found unmistakable traces of the fissures, in a continuous sort of little trench, about twelve or fifteen inches wide at the widest places on the surface, but generally not more than eight inches wide, and of a blunt V-shape, in cross section, with rounded edges, and about eight or nine inches deep. The whole interior surface between the lips was free from vegetation, which latter grew in many places close up to the edges, and corresponded on opposite ones. There was no denying the evidence of a recent fissure, filled up still more recently by the slow sinking together of the sides, and by the washing in of earth by rain. Mr. Mallet was enabled to trace it along the surface, with but occasional breaks of continuity where the rain had washed alluvium transversely and filled it. He was informed by the same soldier (whose testimony had thus proved trustworthy) that he had himself traced the fissures for nearly two Italian miles in a west and southwest direction, which was one generally *coinciding with the horizontal contour along the slope of the hillside.* Another fissure is described in which one side of the V was greatly higher than the other. In both it was considered manifest *that the fissure was the evidence of a great earth-slide,* and had *resulted, not from any direct rending asunder of the ground or rocks beneath it, but that the clay masses had, when shaken violently upon the inclined beds of rock upon which they were superposed, slid down bodily by gravity, and parted off from each other at these fissures.*

The fissures by their direction are considered to perfectly sustain this view, but are absolutely opposed to the idea of fracture, either by shock or by unequal or local sudden elevation or depression of the subjacent formations; for the great *direction in length* of the fissures is *not far* from that of the wave-path here, while it is everywhere but little removed from one, *transverse to a line up* the slope of the hills.

Pertosa stands upon the top of a mound less lofty and steep than Auletta. Pertosa is a very poor place, and with the exception of a few new houses, low, and tolerably well built, with dressed quoin stones and jamb linings, in long blocks, which have stood pretty well, though heavily fissured, all the remainder of the town was built of oblate or ovoid calcareous boulders, of from ten to twelve inches across, picked out of the banks and river beds below, and laid into the walls without any attempt at dressing flat-beds upon them, having also thick mortar joints. The town has hence suffered fearfully, and is almost completely demolished! The timbers of many of the houses after their overthrow took fire, and more than one hundred and fifty corpses of the vast number buried in the ruins were found charred and calcined when disinterred, and in some few cases all semblance of humanity was absolutely obliterated by the action of the quicklime produced from the calcined limestone.

At the south portion of the town the destruction was rather less than over the remainder. Mr. Mallet considers that an obvious reason for this fact is afforded, now that the wave-path is obtained. The plane of the breccia, beds upon which the whole stands, is not very far from being at right angles to the direction of the wave-path ; hence the southern portion of the town received the blow through the *greatest thickness* of these beds; and thus, by the numerous and successive changes of media, in passing from bed to bed, the force of shock here had sustained the largest amount of loss of *vis viva*.

As respects the immediate subject under consideration, Mr. Mallet deems it obvious that any earthquake shock, emerging at a steep angle, and arriving through an immense thickness of beds of limestone first, and of breccia afterwards, before reaching the surface, would, under such circumstances, sustain a vast loss of *vis viva*, and eventually become buffed, with respect to much of its destructive power.

Mr. Mallet was, however, unable to attempt determining whether the breccia beds lie *directly* upon the limestone at both sides of the valley, or may have some other thin beds interposed ; but thinks the first is the fact.

The Military Road at Campostrina, over the rampart that separates the valley of the Tanagro and of the Colore (as its higher stream is here called), is led over the mountain at the eastern side of the river gorge, winding round several lateral valley gorges, and crossing the principal one by an imposing viaduct of considerable altitude, built of ashlar limestone, and carrying a narrow road over a double range of semi-circular arches, upon piers overloaded with material, and buttressed out transversely to the width of the road to more than twice its breadth at their deepest bases. This viaduct must have received the shock very nearly transversely to its length, but emergent at a high angle. It has sustained no damage whatever, though a top-heavy mass;—A SUFFICIENT PROOF OF THE VALUE OF GOOD MASONRY IN AN EARTHQUAKE COUNTRY.

The general direction of the deep narrow gorge, in the bottom of which the foaming torrent of the Tanagro rolls for several miles along, is nearly north and south. The limestone beds at either side, as well as the jagged serratures of the cliffs, in many places vertical or overhanging, correspond to each other, and prove it to have been formed, in the opinion of Mr. Mallet, by separation of the opposite mountain masses.

Polla was an important place, originally, as its name imports ; one of the ancient foundations of the Magna Græcia. Nothing older than middle-age architecture, however, remained before the earthquake; and of this the Castello, near the summit of the town, was the most prominent. Its position in the rich country around, had produced its rapid modern growth to nearly seven thousand inhabitants; and most of its buildings were comparatively modern and pretty well constructed. Its streets and houses, churches and belfries, with olive yards and gardens between, spread themselves over the crown and slopes, to the north, south, and east of the large, low, short and well-buttressed spur of solid limestone rock, which juts out from the mountain range, at the east side of the Vallone di Diano. The lengthway of this spur is transverse to the general line of the valley, and its steepest side is towards the south. The city looked down upon the Calore, slowly and deeply sweeping past its eminence, and upon its own suburb of St. Pietro, at the opposite or right bank of the river, connected with the city by a fine old bridge of Roman style; and to the southward it gazed for miles over a glorious and unbroken hill-girt plain.

Descending towards it, huge yawning gaps began to show themselves, upon the northern and southern slopes, where for acres in extent, everything had been leveled, all traces of streets annihilated; where they had been, immense mounds and sloping avalanches of white and dusty stones and rubbish crowd and encumber the ground. Between these, shattered and leaning fragments of walls, and torn remnants of once lofty buildings, stood in mighty confusion; beams and rafters, tossed up like the arms of the despairing, stood out hard and black against the pallid heaps. The words of the Hebrew bard, referring to a still more Eastern scene of earthquake energy, recurred to memory with a strange reality: "How is the city become a heap, the defenced city a ruin." Months of bombardment would not have produced the destruction involved in an awful shake of only five seconds, during which limited space of time thirteen hundred houses fell together, with deafening crash, and overwhelmed above two thousand of their sleeping inmates; succeeded by clouds of suffocating dust, which choked the cries of horror and anguish that rose from the startled and often wounded survivors. In three different directions *conflagration soon added its terrors to the scene*, and beamed up a flickering and ominous light into that dreadful night of cold and wailing, throughout the lingering hours of which, in helpless agony, they listened to the passionate entreaties for relief, the dying sobs of relatives and friends entombed around them, and dreaded for them, more than for themselves, the recurrence of other shocks.

The cold gray light of winter's dawn, obscure with smoke and dust, revealed hundreds bruised, or with broken limbs, without a roof to shelter, many without a garment to cover them.

On this scene Mr. Mallet feelingly remarks: "It required some hours' familiarity with such scenes, before the mind assumed sufficient composure and capacity for abstracting the attention, in order to pursue the immediate objects of my inquiry." Wherever the walls of the chief edifice had stood sufficiently, at Polla, to observe the direction of fissures, they were found traversing the former at angles indicating steep emergence. In general, however, this angle approached the vertical more at the upper parts of the city, than at or near the base of the hill on which it stood; proving that whatever had been the angle of emergence of the wave at the base, the hill itself, short and stumpy though it was, had vibrated with a proper motion of its own, which being necessarily nearly horizontal, had thus modified the angles of the fissures.

The church of the Madonna of Loretto, at Polla, was a solid Corinthian structure, in great part built of brick, with heavy semi-circular arches to the naves and aisles,—and a heavy semi-cylindric roof; its axial line cardinal. This structure was fissured down to its base; the fissures indicating a wave-path from north to south, and in direction about 160 deg. 3 min. west of north, and an emergence of 50 deg. to 60 deg. with the horizon. The north flank wall leaned heavily out towards the north, as did all the large sashes still standing, high up in the wall. The main mass of the rubbish of the fallen roof fell in the inside of the church, and towards the north side of the floor. The shear or break of the roof vault also, Mr. Mallet considers, proved the direction of the force of fracture to have emerged from the north at a steep angle.

This church was built after the earthquake of 1652, and with special reference to future shocks. Iron chain bars had been built into the arches and roof, and would no doubt have done good service had the shock been more horizontal; but its direction of steep emergence took them transversely, and in several instances *tore them across.*

Everything at Polla, in accordance with Mr. Mallet's theories, consentingly proved a wave-path of steep emergence, and from the north, or very nearly so.

The Capo D'Urbano, a very intelligent man, made a curious and probably not unimportant remark as to his experience of the sound at Polla. He described it as appearing to him to reach him "*through his legs,*" as he stood up; "although," he added, "it,—the sound,—was elsewhere." This, Mr. Mallet considers, suggests the probability that much of the sound in earthquakes may reach the auditory nerves, by transmitted vibration from the ground or other solid objects, through the bony skeleton; just as when a poker held by a string to the ear is struck, and thus may convey from a *very small vibration* an overpowering sense of sound to the auditory nerves.

ATENA, which in Pliny's time gave its name to the whole valley (Campi Atenati),—its name indicating a Greek origin,—is of great antiquity. Here were found some instructive phenomena. Atena is situated upon the east side of the great plain of the Vallone de Diano, and stands upon the crest of a spur of absolutely bare rock, jutting from the lateral range, and having a small transverse valley or gorge to the north of it. The slope or angle of the emergence of the rock, to the width of the town from beneath the deep alluvium, is about 30 degrees with the horizon; the bedding ill-defined, but apparently with a general east and west strike and steep dip. This town suffered terribly. The angle of emergence deduced by Mr. Mallet, from the phenomena observed here of a partially overthrown wall, composed of old and ill-coherent masonry, was 45 deg. to 50 deg., dependent on the adopted constant for the adherence of the mortar and masonry at the bases of separation.

The differences of effect of the same shock, upon well and ill-constructed buildings, was forcibly shown here. The square campanile of the church stands nearly isolated, its north and south side walls being nearly parallel with the axial line of the cathedral. It is about ninety feet in hight, and twenty-two feet square at the base. The walls are three feet eight inches thick at bottom, and only twelve inches at the summit; are very well built, with large, long-bedded, heavy ashlar quoin stones,—three to four feet bed along the face, and sixteen to twenty-four inches deep; cut limestone jamb linings and string courses; and the filling in between these, well-laid coursed rubble. At each of two points of its hight,—viz., the first and second string courses,—the walls are connected by four slender chain bars of $1\frac{1}{2}x\frac{3}{4}$ inch iron, with transverse collars outside the wall faces. This tower has stood uninjured, without even a crack, in the midst of surrounding ruin;—a clear proof of what sound and good building would do, in securing the safety of the inhabitants of towns in earthquake countries.

High up upon the rocky hillside above the town, also, are many summer lodges *(scaffœ)* which are very well built, and of recent date; and although probably a thousand feet above the town level, they have suffered very little; they are chiefly buildings of a single story, and *owe their safety to this*, and *to their good construction.*

A large portion of the ancient walls of the town remain, probably of medieval construction. At one part of these a large cylindrical tower existed, which for ages had been used as a cemetery. From the side of this, overhanging the precipitous face of the hill, a large mass had been thrown, and had exposed to view the surface of a solid cylinder of human bones, of several feet in depth; those at the bottom were reduced almost to crumbled bone-earth, while those on the surface at top were still perfect,—and some not quite denuded of ligaments;—a circumstance showing how ancient in Southern Italy has been the practice of nakedly interring the poor in this barbarous manner,—one still in use at Naples. As interesting to science, Mr. Mallet mentions that many of the bones and skulls had been thrown from the mass along with the debris of the wall; upon the precipitous limestone slope, where they rested, some calcareous springs oozed out, and their deposited tufa was visible; remarking at the same time that it is not improbable that human bones may become incased in tufa, and the latter may hereafter form at this spot a coarse conglomerate, with the fallen masonry and imbedded bones.

Diano is described by Mr. Mallet as having suffered comparatively little by the shock; there being only some fissuring, and a few of the old ill-built, miserable class of houses having been thrown down. This comparative immunity from destruction Mr. Mallet explains as arising from the circumstance that the direction of the wave-path was here nearly due north to south. It therefore passed from the deep clays of the piano into the long spur or colline of the town, losing a portion of its *vis viva* at the junction, and a still larger portion in passing through the great number of nearly vertical beds of limestone,—in a direction perpendicular almost to their planes;—like a bullet shot through the leaves of a thick book.

Again; the shock transmitted southwards through the lengthway of the great flanking chain to the westward, was almost completely cut off from reaching Diano at all, by the Vallone del Raccio to the north and northwest of the town; upon the southwest side of which, on the steep slope of Monte Mattola, the effects of the partial extinction of the wave at its surface as a "free or outlying stratum" were visible in considerable falls of projected rock (loose masses chiefly). Nothing of the wave passing along the flanking range reached the town, therefore but secondary waves of refraction and dispersion; coming up from beneath the town, as the residue of the unextinguished original wave passed southwards.

Few better examples than the case of Diano may be found of the important effects of local condition in modifying the effects of shock, or of the care necessary to observe and disentangle the phenomena. Of towns situated within three or four miles of each other, one is sometimes found almost totally destroyed, the other scarcely injured. It seems almost inexplicable at first sight, that both should have been almost equally near to the same subverting agency from beneath; yet Mr. Mallet claims that nothing can be simpler or more certain when explained, than the conditions which shielded one and left the other exposed to destruction.

Much farther to the westward, Castellucia, Ottali, Corbeto, Laureno, and some other towns, were greatly damaged where Mr. Mallet considers the earth-wave must have been propagated with much violence, but with frequent and rapid changes of direction; and hence rapid loss of *vis viva* and speedy extinction.

Returning to the valley of Diano, upon a new piece of the military road not yet used between Atena and La Sala, Mr. Mallet observed and describes a newly-erected culvert of three semi-circular arches of twelve feet span, passing a torrent under the road; the piers, about eight feet in the opening, all built of good squared ashlar, the arches turned in brick, two bricks thick. The structure was not loaded with material, and was well put together, and the mortar still green. IT DID NOT EXHIBIT A TRACE OF INJURY.

At La Sala the mountain peaks to the rear and above the first low range of the eastern flank exhibited evidence of increased looseness and softening of the limestone rock composing them. The forms of the mountains behind also indicated a very soft and easily denuded or weathered rock; one of low elasticity, and capable of transmitting impulse much less powerfully, and to a much less distance, than the limestone previously encountered, which at its maximum hardness and sonorousness, was found in the flanking peaks of the valley of the Tanagro, some twenty miles to the north.

Many isolated houses and other buildings, about La Sala, founded upon the deep clay of the Piano, exhibited by their fissures, an almost completely uniform direction of wave-path, north to south, and an angle of emergence so small as to seem almost zero. It was obvious, however, that wherever such buildings were founded upon the limestone rock, on the gentle slopes of the lowest hillsides of the east side of the Vallone, the wave-path tended a little to the east of north; i. e., it appeared to come from the line of the eastern flank range, more or less, but still with the prevailing north to south path,—the divergence towards a northeast to southwest direction being from ten to twenty-five degrees; and the angle of emergence at once changed from nearly zero to a pretty large one, which, however, gradually decreased on traveling south.

Nearly opposite the same town was observed at a quarter of a mile distance on the plain, several large haystacks leaning over at the top, very much to the southward. They had their longer axes nearly east and west, and all were thrown to the south, without any twist. The people in the vicinity said these haystacks had all been built plumb, and were so before the shock, a fact claimed by Mr. Mallet as an interesting proof that a very light body may be overturned by a shock, equally with one of great density, the inertia of motion being exactly proportioned to the weight.

La Sala, although a town of Roman, if not of earlier origin, and at present exhibiting remains of much antiquity, about the old Castillo, lying above the town,—is nearly all now composed of wooden buildings, and upon the whole, far better built than any town that had hitherto been visited in the Vallone. It extends for nearly a mile and a quarter along the slope of the hillside; the buildings rising above each other, and presenting, very generally, their greatest length in a north and south direction, or parallel with the hillside, which is nearly continuous, and unbroken by any deep, lateral gorges, along the east side of the Vallone. This town is the seat of government of the province, and contains many large official and other structures. All are more or less fissured, but the actually demolished buildings are few.

This seems to have arisen *less from the diminished energy of the shock here than from the substantial character of the buildings*, and from the fact that almost all of them presented their long dimensions to the line of shock.

At this town Mr. Mallet found Sotto Intendente, H. Cavaliori, Gen. Calvoso, living with the signora in a comfortable wooden "barrac" or hut beneath the town; for although the great shock threw down a few buildings here, the alarm of subsequent minor ones had caused those who could to desert, for the present, their permanent stone houses. He accompanied Mr. M., with his Secretary, H. Caval, Ferdinando Lausalone, through the town and through his own palazzo (the casa officiale), which, though shaken and fissured, was still standing just as it had been fled from, by every living being, on the night of the 16th of December; and as it had been locked up ever since, the pictures and many other objects within the house, were lying strewed or thrown about exactly in the position in which the shock had left them. The Sotto Intendente, on the spot, gave a graphic and intelligent account of his observations as to what had occurred.

The house of the Sotto Intendente was founded on the solid limestone rock, being a long and rather narrow two-story building of large size, stone built, with timber and tiled floors and roof, and well constructed. There are a few small fissures in the walls, indicating a north to south wave-path, emergent twenty to thirty degrees, but the latter evidence uncertain.

The long axis of the house has a direction twenty degrees west of north. The room occupied by the Sotto Intendente, with his family, on the 16th of December, is a nearly square one, on the first floor, (i. e., one over the ground floor). They had not gone to rest, and he was first alarmed by a short, sharp rattling, with a jumping vertical movement of about half an inch, of a large, white metal chocolatière that stood upon a marble-topped table, touching both the south and east walls. At the same moment he heard the " rombo," which continued during the entire time of the shock. It was described as being not very loud, but very terrible, and " seemed to make the floor, and the whole house to tremble,"—a hoarse and grating rumble. Before he could have reckoned twenty, he thought, the great shock came ; a distinct undulation, which several times swayed everything back and forwards, and lifted up and down simultaneously, the horizontal movement having by much the greater range.

As far as he could judge by his own perceptions, the range of horizontal motion did not exceed half a palm (three or four inches). The movements did not instantly cease ; after these great oscillations, the total number of which he could not be certain of—he thought they did not exceed four or six—but all was quiet after about half a minute (as he supposed), when all the inmates rushed out of the house. He never, himself, lost his presence of mind ; on the contrary, he said that the minutest circumstance of movement, etc., that occurred in the room, from the instant when the chocolatière began to give tongue, seemed to stereotype themselves upon his observation and memory.

A number of glazed lithographs, in flat, wood frames, hung each from a single nail, upon the north and east walls of the room. Within a second or two after the chocolatière had begun to jump and make a noise, those hanging on the northwest wall began to oscillate slightly in the plane of the wall, or from east to west, and the reverse; and at the same instant those hanging on the southeast wall began to oscillate slightly, out from, and back to the wall,—that is, in the same east and west direction. The great shock now arrived, when the frames upon the northeast wall at once began to sway forward and back on the plane of the wall, or in a direction of south to north and the reverse, while those upon the southeast wall commenced the movement out from, and back to, the wall; and for a moment or two he thought they all moved more or less both ways, viz.: on the planes and at right angles to the planes, of the east and west, and north and south walls. The motion ended, finally, by the prints on the northeast wall alone oscillating gently in its plane, with a decreasing motion for two or three seconds, and finally coming to rest.

Of the lithographs upon the northwest wall, the Sotto Intendente pointed out one, and he caused it to vibrate in both ways by his hand, as nearly as he could, to the same extent that he had observed it to move at the most violent period of the shock. The chord of the arc of vibration in the plane of the wall (east and west) was about two inches, and the semi-chord of the corresponding vibration from and back to the northeast wall, was about 1.25 inch. The chord of vibration of the frames on the northeast wall, in the plane of that wall (or north and south) was 7.50 inches, and the semi-chord corresponding, from and back to this wall, four inches, according to these representations.

From the observations just described, Mr. Mallet considered it to be obvious that two wave-paths, *almost* coincident in time, had crossed each other at a sharp angle; the one arriving first being transmitted with more or less of an east or west direction, from the north and south axis of the great range of mountains to the eastward, and having a horizontal amplitude not exceeding two inches; the other, which almost instantly followed, having a north to south direction and a horizontal amplitude of six or seven inches.

Nothing observed, except the chocolatière, gave any approximation to the extent of vertical movement or altitude of the wave, which appeared by it to be about half an inch, at most.

Taking for his datum the position of a dislocated pendule, Mr. Mallet calculates that the lateral movement at La Sala was probably about three and a half to four inches; a range of motion which, made with a velocity as great as that with which a person would reach the ground on leaping from a hight of two and a half feet, furnishes a calculation which may enable many to understand how easily a person may be thrown down when exposed to its effects.

The Sotto Intendente remarked that the buildings situated on the harder limestone of his province (La Basilicata) were everywhere more shaken and injured, than those which were based upon the soft, chalky stuff found at La Sala and farther south.

The Palazzo Romani, near Padula.—Mr. Mallet found at the Palazzo Romani, near Padula, as well as at Polla, an example of that singular circumstance, the working up of the keystone or block of a cut stone semi-circular arch over a doorway, owing to the effects of the earthquake, in place of falling down with the other stones composing the arch. This effect is represented by Mr. Mallet as obviously due to the rocking to and fro of the whole wall in the plane of the arch; the motion being several times repeated,—and hence, the alternate partial freeing and gripping of the keystone between the rocking *voussoirs,* which, moving on the lowest point of the jambs, or at the springing level, would thus become at each oscillation, relatively higher and lower than each other. The keystone, at each alternation, if already tolerably free above, by the fractures of the wall produced at the first moment of shock, would then become moved up, more or less, and finally remain at the hight gained.

In this instance, the key-block has been thus lifted up one and a quarter inches above its former place. It is an example of one of the many cases in which a misinterpretation of the phenomena or misconception of the forces, etc., produce false notions as to the actual movement of the shock productive of them. The attention of Mr. Mallet was drawn to these arches, both here and at Polla, by intelligent men (Syndici and Judici, etc.), as affording positive proof of a sudden drop-down or vertical jump-up of the earth and the buildings upon it.

Padula and its Neighborhood.—Below the town, and nearly upon a level with the plain, and founded upon deep clays, stands the monastery of San Francisco. The greatest length stood transverse to the general wave-path; and it has suffered much. Its walls present fractures complicated by the double shock; but those whose planes approached a north and south direction gave good measures of angles of emergence, which appeared a good deal lower on the less elevated deep clays than upon the higher rocky eminences of the town.

The average of the measurements taken from fissures and fractures, gave an emergence of eighteen to twenty degrees from the north, or five and a half to seven and a half degrees less in the clays than in the limestone rock.

The Syndic of Padula, who accompanied Mr. Mallet over the whole place, was of opinion that the great shock came from the northward, but that it was also "vorticose," or at least in various directions transverse to the main one, and so close together in time that it was impossible to regard the earthquake at Padula as other than a prolonged succession of oscillations, lasting several seconds,—he could not say how many. The second distinct shock was felt about an hour afterwards. The reporter had no means of telling the exact time of that occurrence. He heard the sound, he thought, about the same instant that he perceived the first movement. In these statements Mr. Mallet found the *Judice*,—and three or four of the better class who accompanied the party,—coincided.

From the town and its neighborhood Mr. Mallet proceeded about a mile and a quarter to the magnificent monastery, the CERTOSA DI ST. LORENZO. This noble old monastery (whose size and architectural grandeur rendered it worthy of lodging royalty, before it had been despoiled and defaced during the French occupation, under Murat) is described as being built wholly of the best and hardest quality of the white limestone of the higher adjacent mountains, and founded altogether upon the deep clays and gravels of the piano. It is described as now being shattered and shaken to its foundation, in every portion, by the violence of the earthquake, and presenting characteristics of much more formidable dislocation than the town of Padula.

All its walls, its vaulted church and refectory, and very many other grand rooms,—the noble groining of its cloisters, and the painted and richly stuccoed ceilings of its library, and many a royal chamber,—are split, fissured and falling. The light and the rain now find their way to these through acres of shattered tiling. Innumerable chimneys, obelisks, parapets, vases, *bassi-relievi*, statues, have been thrown down, disfigured or destroyed. Even the internal framing of the heavy timbered roof was in several places crushed by the fall of heavy masses from above. Nearly all the superbly columnal arcades around its cloistered courts are now seen bulged at the groining levels, and lean out towards the court; the groining is split along the soffits in almost every gallery, excepting one, where alone iron tie-bars across the arch-cord remained, (originally placed in all) after the departure of the French division which was quartered here; a proof of the importance of such bars in constructing buildings intended to withstand earthquake shocks, as well as of their intrinsic value in the eyes of the brigands who destroyed them.

Opposite the front entrance gate of the monastery stands a monument to San Bruno. The general plane of the structure runs east and west, almost exactly. Several of the little obelisks and finials have been twisted from left to right (looking south at it), or in the same direction that the hands of a watch move. Some of its smaller ornaments are thrown down.

In the entrance square, within the walls, looking south from the steps, the whole of the square, pyramidal chimney-caps, upon the east side building are thrown down on to the roof tiling, and several of the balustrades and finials, placed over a mural fountain in the center of the length of this side have been twisted also.

The chimney caps, thirteen in number, were thrown on to the tiling to various horizontal distances, varying between three and five feet, but all with a very nearly uniform direction of 136 degrees west of north. None of the chimney shafts, which stand about five feet above the roof, have been overthrown, though some have been shattered at the top by the chucking off of the caps, which, like the shafts, are of brick, set in mortar.

On entering the front court or square, the campanile is seen over the southeast corner, from the summit of which two large balls of stone had fallen, one of which, with its pedestal (which remained *in situ*, upon a more solid part of the roofing), rolled down over the eave and described a trajectory (a diagram is given in the original work) into the marble paved court, breaking the nosing of a step, rolling thence some distance, and afterwards striking the base of the fountain noticed, "made a cannon" therefrom, and now remains at some distance from the latter.

The great axial line of the whole mass of buildings is north, fifty degrees west.

In the northwest corner of the square, beneath the arcades of the west side, a statue of the Madonna, standing in a niche, has been twisted on its base, and lifted in a final direction, 115 degrees east of north.

Very near the campanile, but far below its summit level, upon the east gable of the front range of buildings, are two remarkable chimney stacks, one of which has been twisted upon its base, at a horizontal fracture, close to the level of the gable, the other standing uninjured.

To the eastward of the front square, the roofs of the church and of the grand refectory, groined and arched buildings of great magnitude, have been heavily fissured. In the refectory, both end gables run up originally against the ends of a brick vault, have parted from it, and presented east and west fissures, open three inches at top on the north, and one and three quarter inches at the south end; while longitudinal fissures of half an inch to one inch wide, run north and south along the soffit. The roof of the church has been still more dislocated. Both roofs are brick vaults. At the upper end of the refectory, the great fresco by Elia, of the marriage at Cana, is fissured and nearly destroyed.

In the Priori Square, one of the most richly decorated portions of the monastery, the whole of the buildings are in a falling state, the vaulting of the surrounding arcade being split on each side of the square,—the north and south sides most formidably, and next to these the east side; the front pilasters, and the story which they carry above them, are all leaning out and heavily fissured.

Entering the great square to the northeast of the last, which, in magnitude, rather resembles the *place d'armes* of some immense "*caserne*," than the court of a monastery;—the groined arches are similarly fractured; the pilasters and story above bulging out into the court, can be seen from within and without, in the line of one of the galleries.

To the westward of the great square, in the private garden of the "*Priore*," amid much other destruction, a limestone vase had been thrown down from the summit of the south pier of the gate at the west side of the garden, the direction of the throw having been 122 degrees east of north.

The blocks of stone of the pier itself have been thrown or shoved upon each other eastward, about half an inch, and the whole of both piers more or less dislocated. •

Mr. Mallet concludes a most interesting chapter by observing:—

"I have thus briefly recapitulated the objects to be specially referred to, for the information they convey. The vast mass of buildings, however, presented an almost unwavering spectacle of destruction; few of the walls or roofs are actually prostrate, but everywhere fissured, dislocated and tottering; all their beauty and magnificence of architectural form and colored decoration still addressing the eye, but accompanied by gaping rents that sadly told that their glory was departed. If repair were possible, the vastness of the cost precluded it; and thus in a few years hence the work of one terrible hour will have made the owl and the bat the tenants of this Cistercian palace.

Almost the only part of the edifice that has escaped serious injury is the grand elliptic staircase leading to the park, at the extreme northern end. This noble work, said to have been constructed by Michael Angelo, is built of fine sawed ashlar, of hard, white, Apennine limestone, everywhere within sight polished. Its preservation, Mr. Mallet remarks, appears to have arisen from its form; the support to the north given by the broad flights of steps, within and without, *and the careful nature of the workmanship*.

Deductions of Mr. Mallet from the Above Facts.

I now pass to the deductions to be obtained from the observed facts here.

Evidence, Mr. M. considers, everywhere exists of a double if not a triple shock, confirmatory of the statements made at the town of Padula, of oscillations in various directions. The main shock was in the primary wave-path, right along the Vallone, fifteen degrees west of north, towards the south, and arriving through the deep clays and loose materials of the plain. This was *preceded*, at a very brief interval, by a secondary shock, transverse in path to this by a certain angle, and derived from the lateral vibration of the mass of limestone on the range of the northeast. Lastly, the primary shock appears to have been reflected from the neighboring mountains further south, and to have returned again, as an *earthquake echo*, through the clays, with very diminished force, arriving last upon the scene.

At the monument of St. Bruno, many of the obelisks and finials were twisted, and some overthrown. Here universal evidence is claimed to have existed of the shock in a path fifteen degrees west of north to south. Here the finials which are overthrown had been thrown directly westward. All those that are twisted are turned from left to right.

There are two distinct trains of earthquake causation, by either of which bodies may be twisted on their bases. 1st, by the action of a *single* shock, when the center of adherence of the base of the object lies to one side or the other of the vertical plane passing through the center of gravity and the line of the wave-path; 2d, by the conjoint action of *two closely successive shocks*. By the first shock the body is tilted up from its base, but not overthrown, so that, for a time, greater or less, it rests wholly upon one edge of its base. While it is thus poised, if another shock bear upon it in any direction transverse to the first, it acts as usual at the center of gravity of the body, to displace it by inertia, in the contrary direction to the wave transit; but the body is held more or less by friction *at the edge momentarily in contact* with its support, and then only; but this edge must always lie to one side of the vertical plane, passing through the center of gravity in the direction of the wave-path. Hence, the tilted body, *while relapsing upon its base*, *also rotates* round some point situated in the edge of its base upon which it had been tilted, and thus it comes to rest in a new position, having twisted more or less round a vertical axis.

If the observer looks due north at a square pyramid, for example, whose side stands cardinal, and it be tilted by *the first semi-phase of a shock* from east to west, the pyramid will tilt or rise upon the eastern edge of its base; and if, before it has had time to fall back, it be acted on by another shock from north to south, the pyramid will rotate upon the bisection, or some other point of the edge on which it momentarily rested, and will hence come to repose, after having twisted from left to right or with the hands of a watch.

If the tilting up had been produced by the *second semi-phase* of the same shock from east to west, then the pyramid would have risen upon the western edge of its base; and the *same* direction (north and south) of the second shock would have produced rotation upon that edge, but, in a *contrary* direction to the preceding, or from right to left, or against the hands of a watch.

Again: If, in the first supposition, the *first semi-phase* of the east to west shock had tilted the pyramid upon the *eastern* edge of its base, and the second shock had been from south to north, in place of the reverse, as before, then the rotation would have been from left to right; and if tilted by the *second semi-phase* on the *western* edge, the second shock, north to south, would produce rotation left to right.

It would therefore appear at first impossible to determine the *direction* of motion in transit of either shock from such an observation. It can, however, generally be discovered upon which edge of the base any heavy body of stone or masonry has tilted, by the abrasion or splintering of the assis, and the rotation must have taken place round some point in the edge. If, therefore, we know the direction of either one of the two shocks, we can always discover that of the other by the rotation observed; and if the time of oscillation of the body be ascertainable, we are enabled to calculate a major limit for the interval of time that must have elapsed between the arrival at the twisted body of the first and of the second shock, when both the wave-paths are known.

With a single instance of such twisting it may be impossible to decide whether the twist has been due to one shock (first case) or to two shocks in succession (second case); but when several bodies, alike or dissimilar, at the same locality, are *all found twisted in one direction*, it is certain to have been *the work of two distinct shocks*, for it is beyond the reach of probability that several bodies should *all* happen to have their respective centers of adherence at the *same side* of their respective centers of gravity; and unless they have, some will rotate in one and some in the other direction, by any single shock; rotation thus produced being always by the center of gravity, moving contrary to the first or second semi-phase of the wave, and carried round the center of adherence by the line joining them as a radius vector; the inertia of motion at the center of gravity, and the resistance of the point of rotation to the edge of the base,—or the center of adherence,—forming in every case the extremities of the dynamic couple.

These principles Mr. Mallet has illustrated by explanatory diagrams. From facts (yet to be adduced) Mr. Mallet found that the general velocity of *translation* of the wave of shock, through the limestone country, was at the rate of 240 yards per second. This, therefore, may be taken as the velocity of translation of the shock here (through limestone). The total time of its transit from the origin (surface velocity) is therefore 33,415 yards÷240 seconds=139.230 seconds; and through the clays and gravels the whole time is 139,230+1,750= 140,980 seconds. The velocity per second of surface translation in the clays and gravels was therefore 33415+402÷141″=239.84 yards per second.

AN EPISODE.

CHAPTER III.

The Palazzo Fino; Don Andrea's Account of His Eighteen Hours' Entombment; Destruction of Saponara; Geology of Tramutola; The Casa Marotta; First Approximate Calculation of the Depth of Focus of any Earthquake.

" Heaven from all creatures hides the book of fate,
All but the page prescribed the present state."—[POPE.

" Philosophy, then, is only valuable when it serves for the law of life, and not for the ostentation of science."—[BACON.

A series of agencies not necessary to enumerate, have conspired to prevent the growth amongst us of that obnoxious feature for an earthquake country, so prevalent in Southern Europe, of erecting buildings with ponderous floors and roofs. Had it not been for accidental circumstances, it is highly probable that such a mode would have been adopted in San Francisco, by following Spanish precedents. Fortunately, this has not been the case. As will be shown at a future stage, fatal consequences may hereafter arise, owing to the deficient character or mode of application of the mortar employed in building in this city, which, although the disastrous consequences may not equal those detailed in the present chapter, may be sufficiently so to cause the residents of San Francisco, at a not very distant future, to curse the purblind, parsimonious and unskillful policy of its present citizens. The mode of obviating, for local purposes, such a catastrophe which may occur at a probably not very distant date, will be found more particularly detailed in the chapter devoted to lime, mortar, etc., bricks, stones, structural arrangements, etc. Admirers of the sensational will find in Mr. Mallet's poetic description, now republished, of what he observed at Montemurro and Saponara, that fiction can be more than equaled by reality. Impressively graphic as the account is, it will be perused with melancholy interest by most readers.

"It was after the sullen sunset of a wet and wild day, before we were able to reach the bottom of the ravine beneath Montemurro. We had mistaken the way in the rapidly gathering darkness, and had to cross the stream again,—here small and shallow,—and to urge the mules, jaded with the long day's march, and the fatigues of the continuous ascent and sticky mire of the last three or four miles, up the steep clay bank beyond and beneath the town, where the deep clays, into which they sank to the knees, were encumbered by the stones and ruins of the houses above, which had pitched out, and shot down over the bank.

It was with much difficulty that the laden animals were got to the summit, which brought us almost directly on to the plateau of ruins, and in a few yards more we stood in front of the great monastery of St. Francisco, on what had been a piazza or largo, and was comparatively unincumbered with rubbish.

A few persons, with a *gen d'arme* and two or three monks were approaching, the men bearing on their shoulders a sort of large, deep, wooden tray, of some seven feet by four, with one or two lights. I guessed what it meant, and as they passed I stood in the stirrups and more senses than one told that three mangled and ghastly corpses formed their burden. It was the last of the day's task to one of the laboring parties, occupied still in exhuming from the ruins, and interring the five thousand human beings that had suddenly found their fate beneath their own roof-trees, in the most tremendously visited of the earthquake cities.

I addressed one of the monks, and handed him Cardinal Wiseman's encyclical letter; but hardly glancing at it, in the twilight, he suddenly turned away, with merely "*Abbiami di che,*" and we soon found ourselves alone, amidst darkness and a labarynth of uninhabited ruins. After wandering about for some time on foot, we found a hut, in which a man (Guiseppe), his wife and her mother, were living, and with some entreaty and liberal promises, got sheltered; sitting up, however, all night, as the hut, which was not above twelve feet by ten, did not afford room for more than the women to lie down.

Three of my muleteers passed the night round the fire of shattered house timber that we kept up outside; the others, with the mules, in the ruins of a large church, not far off. The rain poured in through the wretchedly improvised roof of reeds and boards; and the night passed in weary discomfort, relieved only, after some broken sleep, by Guiseppe's account of the terrible night of the earthquake here, now just eight weeks past. With the first cold gray of swiftly-coming dawn, I gladly sallied forth. The rain had ceased, the cold air felt refreshing. The stars had shone brightly in the dark sky when I had looked out before, and now shapeless masses of ruin rose still blacker against it, wherever I could see. Crossing a space covered with beams and fragments, with deep mud and water from ponded drainage, I clambered up a huge heap, beside the tower of a fallen church, and from the vantage point looked over the desolation of a prostrate city. Alone, and at that cold and silent hour, the impression was one never to be forgotten. I descended at the opposite side, over the massive walls, broken into slips between huge fragments, and on slopes of rubbish. As I reached the level of the interior, something caught my foot. I stooped and found it was a long and broad piece of ancient-looking lace that had decked some crushed altar. While I looked at it, a large piece of wall came toppling from the still standing part of the tower above, and crushed into fragments upon the talus of rubble down which I had just come, and over which I had again to make my way back to our headquarters.

The unfortunate owner of the Palazzo Fino, at Montemurro, Don Andrea del Fino, on the night of the earthquake, was with his wife in bed, his daughter sleeping in the adjoining chamber, on the principal floor. His wife, who was awake, leaped from bed, and at the instant after, a mass of the vaulting above came down and buried her husband, sleeping in his bed. At the same moment the vault above their daughter's chamber fell upon her. From the light and hollow construction of the vaults, neither were at once killed. The signora escaped by leaping from the front window, she scarcely knew how. For more than two hours she wandered beseechingly, but unnoticed, amongst the mass of terrified survivors in the streets without, before frantic confusion permitted her to obtain aid from her own tenants and dependents to extricate her husband. They got him out alive, after more than eighteen hours' entombment, but maimed for life. His daughter was killed; it was affecting to hear him describe how.

As he despairingly longed for release from the depressing rubbish, which the second shock, that occurred an hour after the first, had so shaken and closed in round him, that he could scarcely breathe, he heard issuing, only at a few feet distance, the agonizing cries and groans of his daughter, which gradually became fainter and fainter, eventually terminating in the silence of death. This episode of personal peril and sad adventure cannot be deemed out of place, affording, as it does, a vivid picture of the terrors of an earthquake night where fitting structural arrangements to meet such a catastrophe have been wholly ignored. This palazzo was the only building that remained at Montemurro, which had not been prostrated by the earthquake, or gutted of floors, roofs, etc.; the only lofty fragments remaining anywhere else being the remains of church-towers, etc.

A fitting pendant to the preceding description is furnished by the concluding reflections of Mr. Mallet, on—

The Destruction of Saponara, respecting which he observes: "It is scarcely conceivable that Saponara will ever be rebuilt; the destruction is too absolute to leave sufficient inducement to undertake the removal of the mountainous masses of rubble and rubbish, that must form the necessary preliminary. Those associated with the place will find another site and rekindle these hearths on strange ground, from which their surviving successors will, within another century, most probably be driven forth, by a future great earthquake, from houses as unskillfully constructed as those their sires perished beneath." Is not the last remark equally applicable to the apathetic conduct of many Californians, who feel so desirous of ignoring the subject of earthquakes, in place of alleviating their possible consequences by the employment of all such precautions as may now be reasonably pointed out by a proper use of modern science?

It may be worth noticing that in this part of Italy the number of places possessing the same name, within a limited space, is very considerable. It may be that in many cases the name alone remains to record the prior existence of an ancient city.

Mr. Mallet found at the Castel of Saponara one massive piece of wall at the north side, whose condition admitted of its being used as a tolerable measure of the velocity of the shock, according to his formula; in which measure he estimated it to amount to sixteen feet per second.

About half a mile from the same place, upon the level clays of the piano, he passed an orchard gateway which had two square piers of rubble ashlar masonry, three feet square and seven feet in hight, both prostrated and in directions accurately parallel 140 deg. 30 min. east of north, fractured at the ground level from their foundations. The *mortar was bad*,—and by examination with the hand, he judged had not an adhesion of more than about two pounds per square inch. The wave-path was exactly sub-normal to the piers. The horizontal for fracture from the equation,

$$V = \tfrac{2}{3}\, g \times \frac{b \quad L}{a \quad 2} \text{ is therefore}$$

$$V = \tfrac{4}{3}\, g \times \sqrt{a^2 + b^2} \times \left(\frac{1 - \cos\, a}{\cos^2 a}\right)$$

a being 22° 40′, a=7 ft., b=3 ft., is V=5.14 feet per second.

The total horizontal fracture and overthrow is therefore, V=5.48 +5.14=10.62 feet per second; but e=16°25′—assumed to be as at Sarconi; therefore V=19.62×sec. e=11.04 feet per second, the actual velocity of the wave in its direct path. This result, deduced from *two* similar blocks of masonry, of the simplest and best form (natural seismometers, in fact), and coinciding so closely with previous and distant determinations,—affords a strong confirmation of the correctness of the explanation given of the nature of the higher velocity that overthrew Saponara. The extract just given is inserted as exhibiting one of the simplest and most easily understood of Mr. Mallet's mathematical formulæ.

From circumstances connected with the geology of the vicinity of a neighboring city, named Tramutola, Mr. Mallet deemed it a legitimate conclusion that in this case the shaly, argillaceous rocks, forming so much of the great mountain mass, placed between Padula and the valley of Tramutola, the earth-wave actually did assume a slightly increased velocity over that which it had been ascertained to have had in the limestone; and this fact Mr. M. thinks serves to account for the fearful destruction at Saponara and Montemurro.

The Casa Marotta at Tramutola is a heavy and well constructed building, the walls of which (three stories) were very thick (two feet nine inches) in proportion to its size, and nearly solid for the lower story,—the apertures being few and comparatively small, and the mass of masonry large above the tops of the upper windows; all of which, combined with the good character of its work, conspired to its safety, as compared with Don Antonio Morano's, opposite, which was of brick, in great part, and full of apertures in the walls—a good example of the utterly diverse effects producible by the same shock. This last instance is given simply as one amongst many that could be adduced, of the great additional safety which is obtained by the employment of good masonry.

As a further and highly interesting example of the species of formulæ employed by Mr. Mallet, the following is inserted as a description of the

First Approximate Calculation of the Depth of Focus of any Earthquake.

In the chapter preceding the one which Mr. Mallet has noticed under the above heading, Mr. M. inferred, on satisfactory grounds, that at the Chiesa Madre, Vietri di Potenza, the angle of emergence $e=75°$. Adopting this view with confidence, Mr. Mallet considers, for reasons given, that he had now, for the first time, obtained decisive evidence that he had passed beyond the point of the surface vertically above the origin of the shock; and on comparing the emergence and wave-path ascertained for another town (Polla), with those here obtained, he conceived that that point (the vertical one) must be somewhere between the two towns (Polla and Vietri di Potenza), and not very far to the westward of the line joining them. With these preliminary remarks, Mr. Mallet proceeds to state: "With much curiosity, I made the calculation for *the first approximation to the depth of the focus ever attempted for any earthquake.* On the assumption that this point was in the vertical plane passing through Polla and Vietri, he calculated the emergences—

At Polla, $e_p=55° \ 49'$.
At Vietri, $e_v=75° \ 00'$.

The angle made by the focus by their respective wave-paths being therefore

$$x=180° \ )55° \ 49'+75° \ 00')=49° \ 11'.$$

The distance from Vietri to Polla, viewed as a right line, amounting to 5.35 geographical miles; then calling r equal the distance from the focus to Vietri,

$$\text{Sin } x : 5.35 :: \sin e_p = \text{r},$$

and $r=5.35\times0.828\div0.757=5.84$ geographical miles;
and for the vertical depth, D, of the focus, we have

$$r : D :: 1 \sin e_v : \cos 15° ; \text{ or } D=5.64 \text{ geographical miles.}$$

This, however, Mr. Mallet considers to be below the true depth, owing to the focus being more to the westward than in the assumed right line joining the two towns, which could be corrected by additional trignometrical calculations.

THE SOUND
THAT ATTENDS SHOCKS.

CHAPTER IV.

Sounds not Without their Earthquake Significance; Sounds Heard at Different Places; How the Sound may Reach the Auditory Nerve.

> "Ah Fear! ah frantic Fear,
> I see, I see thee near.
> I know thy hurried step, thy haggard eye!
> Like thee I start, like thee disordered fly."—[COLLIN'S ODE TO FEAR.

If the total amount of unpleasant feelings created by the alarm arising from sounds originating from earthquakes could be concentrated, it would be found probably to more than aggregate that occasioned by the more fatal dynamical effects of the earthquake shock. This view was vividly impressed on the mind of the writer between ten and eleven o'clock of the morning of the 21st October, 1868, as he witnessed the rushing to and fro of frightened people in all directions on the occurrence of the sound which accompanied the great second shock which took place on that day—the alarm, no doubt, having been greatly augmented at that time by the unallayed alarm excited by the severe shock at eight o'clock A. M. On this account, as well as others pertinent to the subject, that phase of earthquake topics associated with sound is deserving a few words of notice.

The occurrence of sound at all, necessarily implies *impulse* at the focus, of the nature of a blow or a succession of them; either due to fracture of hard and elastic material, the sudden separation or rending open farther of existing fissures and cavities, or the sudden rush out of highly elastic steam, or its as sudden production or condensation, so as to produce a musical note like those due to the impulse of wind in an organ pipe,—or explosion, more or less sudden,—as from the rush from the tail of a rocket to the explosion of a shell or mine.

The character of the sound heard in the shock of December, 1857, however various at different points, was everywhere made up of sudden explosive reports (one, if not more than one), variously contemporaneous, accompanied with rushing and rolling sound.s

It was not confined in a superficial area, co-extensive with the shock, but the form of the area within which it was heard was closely similar to that of the two first isoseismals generally, so that the same conditions that were favorable, or the contrary, to the distant propagation of the wave shock, were about equally so to the wave of sound; but the latter was the feebler of the two, *ab origine.* Echoes, the disturbance of local noise at the moment, the uncertainty with which the ear judges of direction of sound, the evanescence of the phenomenon, and the difficulties inseparable from trusting to merely collected information from often incompetent observers or unfaithful narrators, who observed under alarm, must even deprive sound phenomena (except when heard by the physicist himself) of the unerring certainty of deduction that belongs to the mechanical problems, presented by the phenomena left after the shock.

Sounds, however, are not without their earthquake significance and response, and when more of their complex conditions shall have been submitted to careful *a priori* discussion, we shall be much better prepared to put the inquiries as to facts that will be valuable in results.

No *sound* whatever was heard to *accompany the shock* of the Neapolitan earthquake of 1857, except within a very limited portion of the central area of great disturbance.

The narratives of those situated towards the *northern and southern extremities of the sound area*, all described what they had heard as a low, grating, heavy, sighing rush, of twenty to sixty seconds in duration; some thinking that it was also a sort of rumbling sound, but with none a distinct, well-defined explosion, or several in succession.

Those who were situated towards the middle of the sound area, and towards its east and west boundaries, on the contrary, very generally described the sound as something of the same character as to *tone*, but with more rumbling, using the words "*rombo*," "*rumore di carrozo*," etc., more,—such as "*fischio, sospiramente*," etc., less;—as shorter and more abrupt, both in commencement and ending, and in duration.

From facts observed, Mr. Mallet was led to infer that the center of effort was not confined horizontally to a single or a very small point of space,—nor diffused horizontally and equally round the main focus, over a very wide one; but was limited to a surface, which passed through the main focal point nearly beneath Caggiano.

Such conditions would be fulfilled were the originating impulse due to a great rent or fracture suddenly produced in the course or direction of this curved plane passing through the focal *loci ;* and this is exactly the condition that will account for the sounds so variously heard and described at different points of the shaken area.

Mr. Mallet describes the variation of sounds heard in different places to variation in position, as respects obliqueness or verticality. On this point, under certain conditions, considerable stress is laid by him upon the possible effects of highly compressed steam. To explain some of his views, Mr. Mallet draws an analogy to that of a spectator standing a long way off from the center of the front or rear of a long line of troops, arrayed up and down the slope of a steep hill, who fire in file, commencing in the center, or standing at the same distance from one extremity of the line. In the former case, the spectator would hear the whole sound in less time, nearly as one-half is to one, than in the latter ; while the explosive-like character and loudness would be as two is to one, owing to twice as much sound impinging on the ear in the same time.

Mr. Mallet concedes that the same sort of continuous sound, variable in duration at different stations, could be produced by a single sound or explosion, occurring simultaneously along the whole length of a line,—such as that of an elongated fissure,—owing to the sounds from the different points arriving at the ear in succession as they come from a greater distance ; such a case being analogous to the rumbling of thunder simultaneously produced along a lengthened flash of lightning, so far as our senses can take note of it.

But to this view he objects—

First.—The sound in that case could be *nowhere* "sospirante ;" it would be everywhere rumbling, and only vary in loudness and in length of duration.

Second.—Bearing in mind the extreme velocity of propagation of sound in solids, as compared with its velocity in air, the assumption of a single explosion must involve the existence of a line of simultaneous rupture, of enormous and improbable length, to account sufficiently for the prolongation of the sound.

Third.—The physical conception of any such simultaneous fractures, or of any force, or mode of application of forces, capable of producing it, is difficult, if not impossible.

It may therefore be concluded that the sounds heard in the Neapolitan earthquake of December 16th, 1857, were due to the rending and probably filling with high pressure steam of a rent, commencing at or near the main focal point, and extending (as indicated by the wave-paths) about seven and a half geographical miles in length. Mr.

Mallet afterwards adduced reasons to show that the extreme dimensions of this rent exceed that extent considerably, adding that the production of the rent was the original impulse of the earthquake, its repletion with dense steam, or a further extension of it,—produced, probably, that of a dense shock.

A great deal of obscurity as yet hangs over the way in which the sound from the earth reaches the auditory nerves; whether or not, by vibration communicated from the earth's surface to the stratum of immediately super-incumbent air, and by it to the ear. Upon this point, the remark made by a party at Polla, that he heard the noise come up through his body or legs, from the earth, is noteworthy, as a matter of study, the probability being that the sound, from its starting point, travels to the ear in two ways, viz.: through the earth and human body, directly to the ear,—and through the earth (vertically, or nearly so, to the nearest point in the atmosphere) and thence, through the atmosphere to the ear; and as all evidences concur to establish the fact that the rate of transit of sound is much more rapid through the crust of the earth than through the atmosphere, this would tend, possibly, with other causes concurring, to aid the continuity of sound.

Though highly interesting to the mathematician and the geological physicist, it would be tiresome to the general reader to enumerate and describe, even briefly, the various formulæ which Mr. Mallet has drawn up for explaining and calculating varieties of the phenomena associated with earthquakes. He considers that waves of very small amplitude, at the commencement and end of earthquakes, are the cause of tremors, and most probably of sounds.

These waves, he contends, of small and large amplitudes, *start in succession,* the tremulous wave first, then the shock wave of large amplitude, and lastly, the concluding tremulous wave, the sound waves probably accompanying all,—and if the velocity of inceptive rending be sufficient, the sound waves setting out the earliest of all; so that at a distant point of surface the observer will *hear* the mutterings of the earthquake *first*, will then *feel the tremors* before the shock, *then the great shove of the shock itself*, and, *lastly*, the tremors with which it departs, along with the sound. Adopting Mr. Earnshaw's mathematical views of the progression of sound, it would follow that the transit rate for the wave of large amplitude (the shock) must be greater than that for either of the tremors or the sound. If this is true, an additional reason would be afforded in explanation of the commonly observed fact that the duration of tremors, before and after the shock, is unequal. Mr. Earnshaw's conclusions as to the necessary formation of "breaking waves," when the transit velocities are unequal, have extremely interesting relations with this part of the subject.

Mr. Mallet enters minutely and scientifically into the consideration of the question, how far the transmission of sound to a distant point may be affected by the form of the focal cavity. This, however, need not now be taken into consideration, especially as such a thing as a cavity, such as Mr. Mallet appears to presuppose as the accompaniment of every great earthquake shock, will not be entirely admitted by very many geologists.

The observers of the shock of December, 1857, described to Mr. Mallet their sensations, as follows:—

It began everywhere with the tremors, the sounds generally arriving at the same time. The direction of movement of the tremulous oscillations appeared rapidly to change,—and still more rapidly they increased in amplitude; then the great *shove* of the destructive shock arrived; in some places rather before, in some a little after, the moment of loudest sound. It died away suddenly (i. e., with extreme rapidity), into tremors again, but differing in direction from that of the great shock itself.

To this chain of phenomena, the exceptions observed were only remarked at Naples and in Terra di Lauro, where Mr. Mallet claims that the direction of movement of all the oscillations (the whole being small) did not change, and was in all cases *horizontal*, or apparently so: but the exception here Mr. Mallet considers confirmatory of the explanation, because on account of reasons adduced by him in a prior part of his work, he considers that the shock felt at Naples was the result of reflected and refracted waves,—transmitted horizontally, or nearly so, from an origin of a totally different character from that of a focal cavity, namely, the axial line of the St. Angels range of mountains. Another condition productive of tremulous waves remains to be noticed, which Mr. Mallet claims to occur in any case in which a shock is transmitted, from a center of impulse due to the *compression* of the walls of a focal cavity, in an elastic medium.

From the experiments of Wertheim and Breguet, on their linear and transversible vibration of stretched iron wire, they found the rate of propagation of the latter greater than that of the former, in the ratio 4,634 : 3,485, Mr. Mallet infers that small surface transversible shocks may be in like manner transmitted more rapidly than the direct shock, over an equal distance; hence, the time which the tremors may be felt, *before* the shock, be proportionately prolonged.

COSMOGONY AND SEISMOGONY.

CHAPTER V.

Introduction; Description of the Earthquake at San Francisco on the Eighth of October, 1865; Carbon, Boron, and Silicon—Their Probable Cosmical Importance Hitherto Overlooked—Their Properties Calculated to Afford the Best Illustration of General Cosmical Phenomena; Influence of Heat, Electricity and Magnetism, as Sources of Earthquake Phenomena.

> "There are more things in heaven and earth
> Than are dreamt of in your philosophy, Horatio."—SHAKSPEARE.

> "Cease then nor order, imperfection name,
> Our proper bliss depends on what we blame."—[POPE.

A considerable portion of the present chapter has appeared previously in San Francisco journals; much of that relating to cosmogony formed parts of a series of papers, denominated "The Age of the Gold-Bearing Rocks," which first appeared in 1863, in the *Alta California*, and afterwards re-written and adapted for the *Mining and Scientific Press*. In the series above named I first published the opinion (the reverse of the one generally accepted) that gold in quartz veins might reasonably be expected to be found in geological formations younger than the paleozoic, in which only it had heretofore been held that gold could be successfully sought, by ordinary mining, as distinguished from obtaining gold by washings—diggings. I may briefly mention that it was by the perusal of Sir R. Murchison's "Russia and the Urals," immediately after its publication, that I arrived at that conclusion. At the time that I first named this to the then State Geologist, no discovery had been made in California fully confirming the soundness of this theory, which was one that I had held since somewhere about the year 1846. During the interval, I had named the matter to only a few, and if any, only one person is now living to whom I submitted my theory. This occurred at Flint, in the year 1849. If this *brochure* should meet the party's eye, and he remembers the circumstance, I will feel obliged if he will address a letter to me on this point. I have, at more length, perhaps, than the subject merits, inserted the above details, and should not have done so had it not been that a short time since (the fall of 1868) Mr. M. Attwood, of this city, favored me with a perusal of a lecture on Chemical Geology, delivered by his brother-in-law, David Forbes, F.R.S., before the Fellows of the Chemical Society, London, on February 8th, 1868. This lecture was republished in the columns of the *Mining and Scientific Press.* In the lecture named Mr. Forbes made allusion to the circumstance that he had, in a paper on the geology of Equador, read before the Geological Society, London, about the year 1860, stated that gold-bearing veins were to be found in that part of the world traversing strata of secondary formation. The existence of the paper last named was, however, unknown to me until the time above named, nor had I any opportunity of even cursorily perusing it until the present month (April, 1869), during which a series of the geological transactions was received by the San Francisco Odd Fellows Library. The sequence of the irruption to the surface in geological time, of the metals gold, silver, copper, lead, antimony, tin, etc., will, if carefully studied, be found not to have occurred nor have obtained their present positions, relative to the surface of the earth, until a late period, geologically considered. In fact such metals were not required by the wants of the then animal creation, and they were not needed until MAN made his appearance on the surface of the earth, endowed with faculties to extract, reduce and utilize them.

As will be shown by a republished letter written by me respecting the San Francisco earthquake of October, 1865, I have long held, and still adhere to the opinion, that human access to these valuable metalliferous accessories to the luxuries, comforts, and necessaries of human life has resulted from earthquake influences. The earthquake, in fact, being one of the cosmical agents employed by the great DESIGNER OF ALL, for contributing to HIS final aims.

"The earthquake which occurred on the 8th of October, 1865, will ever be a memorable one to the then residents of San Francisco. During a residence of ten years in the city, many shakes have taken place of greater or less intensity, but, as far as the writer's observations have gone, falling short of phenomena described as occurring in countries where earthquakes more frequently occur. Believing that correct views respecting earthquakes are calculated to illustrate the manner in which mineral veins are formed, and partially filled with their valuable metallic contents, I have for many years—in fact long prior to my arrival on this coast—been desirous of personally witnessing an earthquake of intensity sufficient to afford a general impression

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as to the probable exciting cause which gives origin to the eccentric disturbances of the earth's surface, such as was witnessed in San Francisco on the occasion under notice. I have felt more desirous to witness such an event, as on almost all the previous occasions of terrene tremors in this locality, my own impressions of the direction of "the wave" have been exactly the reverse of that reported by the newspapers. Even on the late occasion, several—probably a majority—described the wave as passing in a direction the complete reverse of what I felt it to be.

I have waited to learn what might be reported from distant places, and sufficient time having elapsed to render it improbable that anything new will arise hereafter, I take this opportunity of recording my own impressions. Previous, however, to giving the details, I wish to call particular attention to one important fact, namely: that although the earth's tremor was distinctly felt one hundred miles north from San Francisco, and possibly exercised an influence at Mount Hood, as well as more than one hundred miles to the westward from the Pacific shore, yet, singular to relate, no report has appeared that the earthquake was felt south of the southern margin of the bay of Monterey; yet on the northern margin, not twenty miles distant, the earthquake exhibited its most violent and destructive effects, namely: at Santa Cruz and along the lower part of the Pajaro river. For the convenience of the distant reader who may be unacquainted with these localities, it may be mentioned that Santa Cruz and the Pajaro River lay about one hundred miles, in a direct line, south of San Francisco. Nor were the disturbances felt at any distance from the coast—no ocean-going vessel having felt them; but coasting vessels, only a few miles from the land, and boats in the bay, felt their effects, which have been almost invariably described as resembling those which occur if some huge sea monster was making a rubbing-post of the bottom of their different barques. I shall hereafter briefly allude to these circumstances, and shall now proceed to describe my personal impressions and observations.

Owing to indisposition, I had not left my bed, and was, consequently, as will be hereafter shown, lying in a position better calculated to remark the course of the two chief shocks than the bulk of people at midday. In corroboration, however, of my own observations, I may mention that a few minutes previous to the occurrence of the shock, Mrs. R. had come into the room with a newspaper, and for the convenience of light was reclining on the bed in an opposite direction to that in which I was lying, her head pointing nearly due east, mine nearly due west. Both shocks were felt by me, first at the right shoulder, and thence passing off by the left foot; while Mrs. R. described the feeling as if the wave first touched her left foot, and passed away over the right shoulder. These facts, together with others which will be hereafter mentioned, have satisfied me that the two great waves of disturbance flowed in a direction from west to east. Previously, however, to the commencement of any disturbance occurring in that direction, we both had our attention drawn to a kind of rubbing and lifting taking place at the southwestern corner of the house, which must be pretty nearly in a direct line north of the probably initial point of disturbance, near the mouth of the Pajaro River. The rubbing impression was stronger than could be expected to be occasioned by any ordinary-sized animal, and the lifting gave rise to one or two jerking sensations, as though the house and supporting posts had been bodily lifted from the ground about a quarter of an inch, and afterwards suddenly dropped. This caused Mrs. R. to call my attention to the subject, inquiring what was the cause. Having simultaneously remarked the circumstance, I gave it, as my opinion, that it appeared like the commencement of an earthquake. She replied she thought it was something of the kind. Immediately succeeding the last remark, the first west and east wave occurred, feeling much the same as what is felt on board a large vessel when a heavy sea overtakes and passes under her without breaking. The second wave, which soon followed, came more abruptly, accompanied with something like a sharp blow or thud, which was felt as though coming from immediately beneath, and was immediately followed by a most indescribable series of complex motions, as if the house was dancing in a broken sea, in a manner similar to that in which peas or sand are made to dance in a tambourine, the bottom of which is being disturbed with slight blows or movements of the finger. At the climax of this singular disturbance, all motion suddenly ceased; the instantaneousness of which was probably as startling as any of the phenomena connected with the earthquake. Prior to the ceasing of the movements which have been just described, I was more than once upon the point of rising for the purpose of viewing the bay, and to ascertain what was occurring at the surface of the earth around me; for I was prepared to see the one greatly disturbed and the other fissured. I was, however, kept in my recumbent position, noting the fantastic flings and jigs which the room was making in its eccentric fandango.

On rising and viewing the bay, to my great surprise nothing unusual was noticeable. As, however, I stood at a distance of fully one thousand feet from the margin, such an appearance is by no means incompatible with the observations made by others sailing over its surface—that it was covered with air bubbles and broken waves; both of which facts have been alluded to and reasonably accounted for in articles which have previously appeared in this journal. I have been minutely circumstantial in describing the occurrences as they appeared to me at the commencement of the earthquake, in part from a desire to draw attention to the time which it has been stated to have lasted. The conversation named (which was not hurried) must have occupied fully if not more than the fifteen seconds commonly attributed as the time which the disturbances continued. Perhaps, however, the preliminary crunching motion from the south has not been included in the fifteen seconds mentioned as the duration of the earthquake. In fact, excepting some neighbors to whom I mentioned the former circumstance, I have not seen or heard any mention made of the grinding or crunching motion alluded to as coming from the south; yet there was such a motion, and accompanied by a pressure of great power and intensity, the most marked exhibition of which was displayed by some pieces of the rock being thrown out of place, situate on the south side of a stone-quarry, which is opened in Centre, between Jersey and Hampshire streets; and if the buildings, with one exception, together with the cracked walls, occasioned by being built on new and unconsolidated land, are examined, it will be found that nearly all the damage which occurred took place on the west and south walls of the structures injured. The exception is Popper's building on Third street, where a large part of the southwest front caved in. This was evidently occasioned more by the giving way of a pillar, or a slight arch, rather than by the earthquake shock. Two gentlemen of my acquaintance were conversing on the opposite side of the street at the time, and they describe the affair as a sliding down, apparently, in consequence of some weak part having succumbed, rather than as thrown down by the shock. One gentleman, driving a buggy near the Mission, assured me that he was not aware of the earthquake until informed of it on arriving in the city. Another, passing up Jackson street in a railway car, immediately preceding the falling of a wall then in course of erection, did not feel the shock or become aware of it until he made some inquiries in consequence of observing several excited groups of people.

The great physical phenomenon, however, is the fact that from the northern shore of Monterey Bay to Mount Hood, a distance of more than six hundred miles, the disturbances were more or less apparent, terminating at Mount Hood in volcanic action, and at Goose Lake, in the Sierra Nevada, in numerous water-spouts, whilst the shock was not sensible for hundreds of miles south of these points.

This description has reached a greater length than I anticipated, and compels me to omit some other incidents as well as suggestions respecting the erection of buildings, in future, in order to avoid accident as much as possible from earthquakes."

On the occasion of the earthquake which took place at San Francisco at eight o'clock, A. M., on the twenty-first day of October, in the year 1868. I had risen from the breakfast table, although part of a cup of tea supplied to me had been teemed into a saucer. Standing close to the table when the shock arrived, I observed that the cup supplied to Mrs. Rowlandson was brimfull. During the shock, however, about six-tenths of an inch of the liquid was jerked into the saucer, not by an oscillatory movement, but by a perpendicular, jerking movement, the sensation to the feet resembling that as if the rock on which the house is situated, was being rapidly struck by enormous hammers,—in other words, a distinctly marked percussive one. A boiler placed in the kitchen, although covered with a tin cover, was observed to simultaneously spurt out jets of water, wherever it was able to force its way between the lid and the boiler. A rolling or wave-motion, on this occasion, was not noticed, other than by noting the racking noise occasioned by the timbers of which the house is wholly constructed.

Cosmogony is the science which treats of the history of terrene creation. As a part, though an infinitely small one, of the created universe, the phenomena which have occurred during the various periods in the course of which our terrestrial sphere has undergone so many marked changes, must always have a deep interest with mankind, even if their investigation was not calculated to aid the future material welfare of the human race. Such a negative conclusion is, however, by no means probable; on the contrary, the deeper we penetrate into the mysteries of created matter, the more likely are we to arrive at sound opinions on subjects connected with the physical and mental progress of man. Astronomy, even before chemistry had so far advanced as to give the theories of the most eminent observers of the heavenly bodies the aid of its countenance, had demonstrated that their mighty mechanism was governed by the same laws—the grander for their simplicity—which rule on this earth.

Chemical facts not generally known go far to show the probability that the whole of created matter visible to man not only as respects this earth and its satellite, but also the various planets, their satellites, the fixed stars and nebulæ, including the glorious sun itself, the center of *our* planetary system—possess a common origin.

Such was the theory first propounded by Laplace, the correctness of which has been largely corroborated by astronomical and chemical research, the latter having been remarkably aided, of late years, by the adoption of spectrum analysis, for examining the appearances presented under various phases by the sun, planets, fixed stars and nebulæ.

The theory of Laplace is based on the supposition that what to human faculties will ever form an incomprehensibly distant past, all forms and kinds of matter existed in what may generally be termed a vaporized chaotic condition, from which pristine state, by mechanical agencies, the universe, as we now see it, gradually resolved itself. To this, I think, it may now also be added that chemical affinities have had no small share in these mighty celestial and terrestrial arrangements.

It was also Laplace who, from pure, mathematical inductive reasoning, first announced the theory that this globe of ours, after its consolidation from the gaseous or chaotic condition, formed a molten mass, which has since been gradually cooling, and, as a consequence, contracting also; the contraction of the coating of hardened crust formed over a molten interior, is by many, the writer amongst the number, considered as the chief, if not the only cause of earthquakes, the agencies of steam, electricity and magnetism, which are often evolved as accompaniments of earthquakes, being merely effects derivative from the cause first alluded to; others, however, attribute earthquakes to the sudden development of immense bodies of heated water, under the spheroidal condition, and as steam; others consider electricity or magnetism—one or both—as the cause, not the effect of earthquakes. Attention will be given to all these theories, as, however, the writer considers that, with modifications and explanations, the original theory of Laplace more satisfactorily explains a greater number of the phenomena exhibited by earthquakes and volcanoes, and it may be added the formation of metallic mineral veins, also, he hopes he will be excused for devoting by far the larger portion of this chapter to that special phase of the subject.

One of the greatest stumbling blocks in the way of the Laplace—or as I shall term it hereafter, the Plutonic original condition of the earth—consists in the adjustment of the theory with the now well ascertained average specific gravity of the whole earth, which is now found to be equal to something more than 6.00, whilst the crust, so far as known to us, falls short of 3.00, or less than one half of that of the entire earth.* If, however, the gravity of the materials of our globe increased towards the center in proportion to physical laws, the gravity of the entire earth ought to be much greater than 6, 8 or 10. The attention of mathematicians was early drawn to this subject, after Cavendish had first "weighed the earth," and the late Sir John Leslie theorized that the center of our earth consisted of a mass of imponderable light.

The difficulty of reconciling the actual facts ascertained, respecting the average specific gravity of the earth and the physical laws connected with the increase of density in proportion to pressure, are further increased when it is taken into consideration that all probabilities point to the conclusion that the great store of metals, lead, copper, silver, gold, etc., having a high specific gravity, whether as metals *per se* or mineralized as sulphides, etc., lies low down below us. It is true the metals, calcium, magnesium, aluminum, sodium and potassium, are light metals, the two last being lighter than water, but are susceptible of volatilization by an ordinary furnace, a property incompatible with their existing in quantity near a molten mass, such as I have alluded to. Although I am not aware of any experiments made for the purpose, it is probable that the metallic earthy bases are capable, like the so-called alkaline ones, of being vaporized at high temperatures, and at much lower ones than those required by the ordinary and heavy metals.

About the time of the October earthquake, in 1865, a theory attracted my attention, which will be shortly noticed, which caused me to reconsider the subject of the anomalies associated with the specific gravity of the earth, and to endeavor to find by inductive reasoning whether such anomalies could not be reconciled. After carefully weighing all the phenomena surrounding this subject, I formed the opinion that the substances most likely to fulfill the condition required, would be found in

Carbon, Boron and Silicon.

Carbon, boron and silicon are non-metallic, elementary substances or bases, which possess many properties in common.

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*For calculations on this point and many interesting matters associated with the subject of geology, the reader is referred to the lecture of Mr. D. Forbes, previously alluded to. This lecture will be found given *in extenso*, in the last volume of the San Francisco *Mining and Scientific Press.*

Carbon is an elementary body of the greatest importance. Independent of the quantity in which it exists, diffused through the atmosphere in the state of carbonic acid, it forms one of the chief constituents of the numerous varieties of carbonate of lime and magnesia, constituting nearly one-eighth of the entire weight of the former, and more than one-seventh of carbonate of magnesia. It is also a characteristic element in all organic substances, and is familiarly known in the mineral kingdom in the state of coal, anthracite, and mixed with clay, as carbonaceous shales. The exhalation of carbonic acid by the animal, and its absorption by the vegetable kingdom, form one of the most interesting investigations of vital phenomena, and at the same time affords a striking example of the marvelously compensatory adjustment and simplicity of natural laws and means, which both inanimate and animated nature so frequently present. It is by this means that the well-being of the two great divisions of life are ordained to be essential to each other. Fuel burned and dissipated in vapor is again reduced to the solid form, being by the agency of vegetation once more fitted for combustion; while on the other hand, vegetable life, under the influence of the solar rays, absorbs as food the carbonic acid exhaled by animals, which otherwise would, by its accumulation, exercise its poisonous influence on animal life.

Carbon in the form of the diamond possesses the well known brilliant luster and great refracting power for which this gem is so highly prized. Its specific gravity in this condition varies from 3.33 to 3.35, and is a non-conductor of electricity. In vessels from which oxygen or the atmosphere is excluded, the diamond may be intensely heated without change. No heat hitherto applied has been found sufficient to volatilize the diamond, or, indeed, of carbon in any of its forms, though in the intense heat of the voltaic arc, carbon appears to be mechanically transported from one electrode to the other. When a diamond is introduced into the flame of the voltaic arc the gem undergoes a remarkable change. As soon as the diamond becomes white hot, it begins to swell up, loses its transparency, suddenly acquires the power of conducting electricity, becomes specifically lighter, and is converted into a black, opaque mass, resembling coke. The density of a diamond thus changed was found to be 2.0778, while in the crystalline condition it was 3.326; the heat of the oxy-hydrogen jet having been found insufficient to produce the change.

Carbon, in all its forms, from the diamond to charcoal and lampblack, are chemically identical. It is one of the primitive substances exhibiting chemical affinity in least activity at ordinary temperatures;

but like many others, when in a finely divided state, spongy platinum, for instance, it condenses oxygen to a great extent. In the pulverized form, the property of decolorizing many objects, as well as its action so remarkably displayed on putrescible ones, is well known and economically employed to a large extent. At high temperatures, the affinity of carbon for oxygen is great, forming carbonic acid and carbonic oxide, according to circumstances. The valuable properties of various fuels chiefly depend upon this circumstance. In the state of fine subdivision, carbon is a bad conductor of heat, but its conducting power increases with its density. In all its forms, excepting the diamond, carbon is an excellent conductor of electricity, ranking in this respect next to the metals. The property of carbon as a de-oxidizing agent at high temperatures, especially in metallurgy, is too well known to require dwelling on.

The term *allotropic*, or changed condition, is now generally applied to the varied form of substances, such as carbon, phosphorus, etc., which in different forms possess an identity of chemical composition, yet presenting changed appearances, as instanced in the case of carbon in the different states of diamond, graphite, charcoal, coke, lamp-black, etc.

Reference will shortly be made to some of the properties of carbon, above described, as possibly having been, and as still being, an important agent of Cosmogony.

Carbon, in its purest state, is found colorless, in a crystalline form, as transparent diamonds. It is, however, more familiarly known in a less pure condition, as graphite or plumbago and ordinary charcoal. I shall not dwell upon the varied conditions under which carbon is found in nature; what has already been stated will suffice for such a familiarly known subject.

The characteristics of boron and silicon, in their primary condition, are much less, in fact, scarcely at all known, and will thus excuse some more lengthened remarks respecting each.

Boron is not known in an uncompounded form in the mineral kingdom, though to some extent it is found naturally as boracic acid in the Tuscany lagoons, and as boracic acid, combined with soda, in the Tincal lakes of Thibet, and at Clear Lake, in this State. The same acid, combined with lime, is found in South America. The chief minerals which contain it are schorl and tourmaline.

Boron is a combustible radical, in like manner with iron, carbon, copper, calcium, etc., and burns at a high temperature, similar to those substances, when heated in the presence of oxygen. Boron has hitherto been obtained by decomposing the compound so formed (boracic acid) or its combination, with fluorine and potassium (borofluoride of potassium). Boron hitherto obtained by these means generally possesses a dull, olive-green color, and is in the form of powder, which, before it has been strongly ignited, will soil the fingers, like graphite, and is to a very slight extent soluble in pure water, forming a greenish-yellow solution. Boron is unacted upon by exposure to air, water, or alkaline solutions, at common temperatures, either cold or boiling. The first experimentalists found that after exposure to intense heat, in vessels from which air is excluded, it becomes denser, and dark in color, but failed to crystallize or fuse it. In the form first described, boron exhibits a strong affinity for oxygen, and takes fire below redness in heated air; burning with a red light, and emitting vivid scintillations, if surrounded with pure oxygen. Boron thus becomes superficially converted into boracic acid, which melts, and thus protects the boron in the interior from further action. Deville and Wohler have, however, succeeded in crystallizing boron, which, although artificially produced, is said to have possessed a brilliancy almost equal to the diamond, and of an exceeding hardness. Fused, or as it has commonly been termed, glass of borax, has long been employed as a flux by assayers, and although it occasionally looks like well polished glass, it is by no means comparable with the diamond, either as respects hardness or durability. It may be worth mentioning that the best imitation of the diamond, so far as brilliancy is concerned, invariably contains portions of boron and silicon.

SILICON, associated with oxygen, is the most abundant mineral substance known to us; its purest condition being seen as colorless quartz crystals. Sand and sandstone rock are nearly wholly composed of it, and a very large percentage of almost all ordinary clays and soils also consist of it.

Silicon, the radical of quartz, is obtained by modes not greatly dissimilar from those for procuring boron. As hitherto obtained, silicon has the appearance of a dull brown powder, insoluble in water, and soils the finger, when touched, like the preceding described elementary substance. When heated in air or in oxygen, it burns brilliantly, and is converted into silicic acid (silica or quartz), which is the only known oxidized form of silicon. The intense heat evolved in the course of ignition causes the silica so formed to *fuse*, and thus inclose the unburned portion of silicon in a superficial coating, impervious to further action. Up to the present period, silicon has never been either fused or volatilized. Devillé, by a peculiar process, succeeded partially, so as to form brilliant plates possessing a metallic luster, although possessing many of the characteristics, which the powder above described presents subsequent to having been intensely treated in a closed platinum crucible; in this condition it has been found to be unacted upon by air or oxygen, even when these gases are urged by a blow-pipe. Silicon, so treated, becomes much denser and of a darker color. It is by no means improbable that silicon may yet, like boron, be crystallized; in which case it is quite possible that a gem may be obtained equal and probably superior to the diamond, as respects hardness, durability, and probably brilliancy also.

Owing to the rarity with which they have been prepared, many of the physical properties of silicon and boron are as yet unknown, but from analogy it is not unfair to assume, in the absence of actual trial, that the two substances named possess qualities not greatly different from that of carbon, other than it having been found that they are not conductors of electricity, at all events, in the forms with which they have been experimented. Like carbon, the non-electric conducting property, may depend upon their *allotropic* condition. This point remains for future research to determine. It is one that the writer imagines will prove of importance, as connected with the elucidation of the science of creation, and it is hoped electricians will turn their attention to the subject. The non-volatility of silicon and boron, by the most intense heats producible by any known furnaces, may be inferred from the circumstances that when even combined with oxygen, as boracic acid, and silicic acid (quartz), they are not volatilizable unless by the aid of steam, a property which it could be shown must have been of great importance in some of the earlier stages of the formation of the earth's crust.

The mysterious, but all-important properties, light, heat, electricity, and magnetism, have been called imponderable bodies or substances, the probability being, however, very considerable that these varied characteristic appearances resemble, in a great measure, what has already been noticed as the allotropic condition of substances, as, for example, carbon in the states of diamond, plumbago, graphite, etc.—thus heat may be made to develop electricity; for the thermo-multiplier of Nobile and Melloni clearly shows that the current of electricity which is produced by this means is exactly proportioned, *cæteris paribus*, to the amount of heat by which it is excited; by means of this current of electricity the development of magnetism can be produced. The ignition of solid matters shows that heat may evolve light, under favorable circumstances, whilst electricity, in the electric spark, develops light and heat of great intensity, if the current is interrupted by the fusing of metals.

All these mysterious agents may and do become latent in matter, a practical illustration of which will be best afforded by the familiar example of a practice sometimes adopted by expert blacksmiths, in order to light their furnaces, which they accomplish by dexterously hammering on the anvil a piece of cold nail-rod iron, until it becomes red-hot, in consequence of the evolution of the latent heat, as it is termed, contained in the iron. The heat being in such instances evolved by the compression of concussion. The iron, in such case, becomes specifically heavier, thus showing that heat, if imponderable, certainly occupies *space*, the last name property being a most important one, as connected with the views which I am about to propound in reference to cosmogony. Before, however, doing so, it may be well to call the attention of the reader or student to the fact that iron once heated thus, cannot be made red-hot again by re-hammering, unless it has again been subjected to the red heat of a fire, by which means the iron will re-absorb the heat which it had lost by hammering. In the same way, heat becomes latent upon liquefying a piece of ice. By means of fire, electricity, magnetism, etc., in a similar manner form latent properties of matter.

The quantity of heat and probably electricity with the other cognate properties of matter which are stored in the inorganic kingdom alone must be incomprehensibly great. For example: What an enormous amount of heat can be developed by the friction against each other of two cubes of polished crystallized quartz (say of one inch measurement) before such cubes would be worn away. If we bear this fact in view, it will not be very difficult to comprehend that, if, in place of being latent, as it is now found to be absorbed in solid bodies, heat was from any cause to become free and diffused, that a gaseous condition of all matter might result. I am quite aware that in our present knowledge of physics, such a condition of matter is not easy of explanation, yet it does not present inseparable difficulties. All that can at present be said is, that mathematical, astronomical and chemical observations conspire to establish the fact that created matter, as far as our faculties can discover or penetrate, was originally an incoherent gaseous mass, throughout which light, heat, etc., were diffused, and was not, as the major part has subsequently become, latent in solidified matter.

What are known as nebulæ formed at one time a topic of dispute with astronomers and physicists, whether they were really nebulous gaseous bodies, the remains of the original nebulous mass, or far-distant bodies, irresolvable into stars, owing to their immense distances and the limited character of telescopic power yet attained. The telescope of Lord Ross and others possessed of greatly increased telescopic power, has shown that many of the hitherto irresolvable nebulæ do form clusters of innumerable stars. It has, however, been reserved, I believe, for the current year* to show that nebulæ do exist. This important fact was obtained by means of spectrum analysis. On applying the spectrum to the analysis of some of the nebulæ in Orion, it was found that lines were afforded on several trials which from their distinguishing characteristics has been pronounced by the observer as being reflected by vaporized carbon, which, if confirmed by subsequent astronomical research, will form a somewhat remarkably strong corroboration of the soundness of some of the statements now being made that are based on an inductive train of inquiry.

Only a short time previous to the remarkable discovery asserted to have been made respecting the nebulæ of Orion, spectrum analyzation had been applied to our sun, by which it has been fairly demonstrated that the exterior margin of that glorious orb is studded with enormous protuberant masses of incandescent hydrogen—the lightest undecompounded body known to us, and probably also one possessed of the most expansive properties of any gaseous substance when subjected to high temperatures. We have, therefore, should the fact be confirmed (which I, for one, am prepared to expect), in the instances given,—first, that carbon, in a vaporized form, has been discovered to be present in nebulous matter such as it is theorized originally filled all space, so far as we can comprehend the limitability of that word. This vaporized carbon is accompanied by a light, fainter, owing to diffusion, than would be evolved from consolidated masses, like stars and suns; heat from the same causes by which light probably was dispersed did not become a latent property of matter, and so susceptible of subsequent intensified evolution under fitting circumstances until consolidation had proceeded to a large extent. In this phenomenon we find that one of, if not the most unsublimable substances known, in the state of vapor, in an unconsolidated and ascertained irresolvable nebulous mass; and in the second case we find hydrogen forming the exterior protuberances of the sun, the center of our system, which, according to the cosmical theory of Laplace, exhibits one of the latest

*My first notice of the fact related was obtained by perusing the last (March, 1869) number of Silliman's Journal.

stages of condensation of matter from a primeval nebular condition. The condensation of nebulous matter into suns, planets, satellites and rings, do not fall within the compass of the present inquiry.

It will probably have occurred to many readers, by the time they have reached thus far, that the connection between the properties of carbon, boron and silicate with earthquakes has not been made very clear. Such an impression would undoubtedly be correct. The writer conceives, however, that the simplest explanation of the cause of earthquakes can only be obtained by first comprehending the cosmogony of our terrene system. The Laplace theory, setting out on the principle that universal matter, and the properties associated therewith, was originally in a gaseous condition, has already been alluded to, as well as the circumstance that recent experiments with the spectrum with some of the nebulæ in Orion, go to establish the fact that the light transmitted from some of these nebulous bodies indicate the existence of carbon in a vaporized condition. The next step pre-supposed by the theory of Laplace, in the cosmical origin of the stellar and planetary systems, is the gradual condensation of such diffused vaporized matter, first into liquid, and afterwards into solid forms, agreeable to their affinities and physical properties, as affected by heat, which latter would necessarily become evolved and active as condensation proceeded. In the course of these changes primitive matter, by mechanical laws, clearly set forth by Laplace in his *Mechanique Celeste*, became resolved into the varied worlds now visible. That comparatively early in the cosmical formation of bodies so aggregated, our earth, as well as others, was in a state so highly heated that the general mass was in a fused condition, is the natural sequence of such a theory; and also, from this last mentioned cause is attributable the oblate spheroidal form of the earth. A cooling globe, the former molten state of the earth's mass, and a molten center at the present time, have been admitted as almost demonstrated axiomatic propositions by the first geologists and physicists of the past, and accepted by the greatest of the present age, which, if a true proposition, and taken in company with what must be a necessary accompaniment of a cooling globe, namely, a gradual contraction of the consolidated crust, these combined will afford a more rational reply to the question so often asked, What are the causes of earthquakes? and account for more of its phenomena than any other theory that can be presented. Steam may, and possibly does play an occasional and subordinate part in earthquake phenomena; but the true *vera causa*, even if such be the case in particular instances, can only be ultimately traced through the active agency of a molten center, magnetic and electric development, which it is not denied frequently accompany earthquakes, being merely derivative from the thermo-electric condition evolved, in consequence of the irruption of heated matter and the dynamic force, pressure, etc., arising from its intrusion amidst the superior lying strata.

I believe it was Professor Alexis Perrey,* of Dijon, France, who, from numerous observations collected respecting earthquakes, first broached the theory that a periodicity occurred in earthquakes in a manner analogous to those of ocean tides,—such phenomena being, however, according to Professor P., the most numerous at the equinoxial periods. That such an influence may exist and is possible I am not prepared to deny; but in such a case, as well as that broached by my friend Mr. W. H. Rhodes,† under certain conjunctions of the planets, it is difficult to conceive how any attractive influence can be occasioned unless a fluid, and, by consequence, a molten center, existed.

Soon after the San Franciscan earthquake of October, 1865, I noticed a theory in some periodical, the title of which I have long forgotten, and by whom I do not now recollect, that the center of our planet is, not simply a mass of fluid, but is compounded of a solid nucleus, susceptible of moving, amidst an enveloping molten zone, and that it is from these so theorized secular movements that earthquakes may chiefly be attributed. The reasons adduced for such a theory did not strike me as very cogent ones at the time that I noticed them, otherwise I should certainly have taken a note of the publication in which they appeared, and also the name of the party who propounded them. Notwithstanding this then indifference on my part, it led me, by an inductive train of reasoning, to infer the possibility of such a solid central mass existing or floating amidst a fluid or molten zone. I should scarcely have been led to the study of this phase of cosmogony had it not been that I had long mentally dwelled upon the anomaly of the discrepancy between the specific gravity of the earth's surface and its known average specific gravity, which has been already alluded to.

Of the ordinary metals and their compounds composing the interior strata of the earth, their high specific gravities generally are such as

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*Professor Perrey is well known as having kept for many years a register of earthquakes, as they occurred throughout the world.

†It is proper to state that Mr Rhodes entirely ignores the plutonic or molten theory of an aqueous center, and attributes any planetary seismic action as being a result of electric agency, which, by that means, he supposes is brought into activity.

would lead us to anticipate that the average specific gravity of the earth would be much higher than it has been found to be by experimental deduction. It is true that the alkaline metals are below the specific gravity of water, and some of the earthy metallic bases are very low also. Sir Humphrey Davy set up the theory that a large part of the deeper portions of the crust of our sphere is composed of the alkaline metals, and are the cause of earthquakes, owing to their oxidation. As, however, these metals are susceptible of sublimation at a comparatively low temperature, such an opinion cannot be made compatible with an excessively high or molten one.

We are not acquainted with any experiments calculated to show that carbon has ever been liquefied, though analogy leads to the inference that, like other bodies, it does not at once pass from the gaseous to the solid form without first passing through the intermediate condition of liquidity. Whether such be the case or not, excepting as a noteworthy incident, it has no bearing on the present question.*

There are, therefore, pretty clearly known to be three substances which, to all analogy, possess allied physical properties, one of the most remarkable of which is that compared with all the other undecompounded elementary substances which we are acquainted with; these three, in the absence of oxygen, possess the common property of remaining in a solid condition at temperatures so elevated that all others, if submitted to the same intensely great pyrital heat, would become fused or sublimed. We have, therefore, in boron, silicon and carbon, substances which most probably did form the first solid nucleus of our sphere, and possibly do now constitute a solid central mass, which may possess a periodical or secular motion amidst an enveloping mass of molten matter. If such, on further research, be found to be demonstrably true, the fact would still further elucidate many of the more obscure phenomena associated with the recurrence of earthquakes.

It will not be out of place to say a few words on the possible corroboration which paleontology and fossil botany may afford, as illustrative of the probable soundness of the views just given.

In the rocks denominated Laurentian by Sir. W. Logan (from the river St. Lawrence), found in Canada and Western New York, the oldest stratified rocks yet known, has been discovered the earliest form of organic life, which has received the name of "Eozoon Canadense."

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*It may here be remarked that carbon has been precipitated from the gaseous state when in chemical combination with other substances. This by no means settles the point whether carbon cannot or never has existed in a fluid or fused form.

In rocks nearly as ancient, found in Scandinavia, has recently been discovered what is now considered the earliest form of vegetable existence, heretofore no trace of such having been found excepting in rocks high above in the geological series, viz: the upper Silurian. It may, however, be mentioned that the point where animal and vegetable life deviates is a debatable one with naturalists. This, however, is not a question that in anyway affects the line of argument which is about to follow, because it is intended to show that whether animal or vegetable organisms preceded in the order of terrene organic life, that in both cases the earliest species discovered clearly establish the probability that they flourished amidst waters greatly saturated with silica, but not with lime, such waters also being probably of a thermal character, a condition well calculated to contain a larger percentage of silica in solution, while at the same time it would be inimical to the retention of carbonate of lime. The fossils found in Scandinavia, above alluded to, and surmised to be the representatives of an early, possibly a primeval, vegetation, it has been stated, very probably belong to early varieties of the carex or juncii (sedge or rush) families, both well known to be tribes which cannot flourish excepting where moisture and soluble silica exist. As far as the writer can judge from the representation of the Eozoon Canadense, given by Dr. W. Carpenter, in the Quarterly Journal of the London Geological Society, it appears to combine a diatomaceous allied to an algal form, both of which by naturalists are classed as belonging to the vegetable kingdom. In whatever way this question may be finally settled, the result will not at all affect the train of argument now being pursued, which is, that whether organic life first appeared on our sphere in the vegetable or animal kingdom, or in a form where the two were combined and subsequently became dissociated by a natural law of differentiation, matters not; the most ancient fossil evidence that has been found, showing by the instances named that the earliest forms of organic life known to us required for their existence a very much greater proportion of silica for the maintenance of their solids than any other substance, carbon and carbonate of lime, which now play such an important part in the organism of both kingdoms, occupying in the earlier stages of organic life a much less conspicuous, in fact almost an insignificant position—,one so small in fact that it affords reason to doubt whether carbon could not, in the case of the diatomacæ, have been dispensed with entirely without fatal injury to life.

Before the discovery of the fossils above alluded to, I had from long study of the subject arrived at the conclusion that the silicious diatomacæ, or something akin thereto, formed the first terrene organism, whether such pertained to the animal or vegetable kingdom. So small a proportion does carbon form even of existing species of silicious diatomacæ, that I have never yet observed that an attempt has been approximately made to estimate its amount. There can scarcely be a doubt but it falls short of the proportion of silica found amongst many plants now existing. Our cereal grains, and the graminacæ generally, may be adduced as instances for this comparison.

Another matter of no little importance in forming a correct opinion on this important branch of cosmogony is the fact that, of all organisms known to us as being capable of flourishing in waters of high temperature, the diatomacæ and the algæ stand foremost, and would, therefore, probably be the first inhabitants of the primeval waters of our globe, which latter must have possessed an elevated temperature, if the reasons primarily assigned are tolerably correct.

I shall conclude this portion of the subject by calling attention to the following facts: First—That the heretofore called azoic rocks, as well as those now known as the earliest paleozoic ones, are composed chiefly of silicious matters, calcareous ones* being in less proportion than amongst more recent formations. Amongst other contributing causes to the great discrepancy, the writer believes that no small part of this circumstance resulted from the accumulation of the remains of silicious infusoriæ, but that the evidences of their existence, from their microscopic character, conjoined with the myriads of eons of time which have elapsed since their deposition, have caused them to have been completely obliterated. Another fact worth recording is, that we do not become acquainted with any notable deposition of carbon until we ascend a long way in the geological series. It may, therefore, be presumed that the time had not yet arrived for carbon to perform the important functions which it has since done in both the organic kingdoms. Lastly, the great comparative rarity of boron is another subject not to be overlooked. The economic sources are rare, only being found in paying quantities in four parts of the world; and, singular to relate, the chief ones are the Tuscan boracic acid lagoons, and Clear Lake, California. That the process of evolving boracic acid from the

*From the solubility of carbonate of lime in water saturated with carbonic acid, it is not only possible, but to the highest degree probable, that the deficiency of calcareous matter in the earlier as compared with later formations is owing to its having been carried off in solutions; making every allowance, however, for the circumstance named, this would not account for the great discrepancy that exists between the amount of limestone to be found in the first and latest rocks of sedimentary origin.

lower depths of the earth to the surface is now proceeding doubtlessly in consequence of internal heat, is manifested not only by the Tuscany lagoons, but also from the circumstance established by Dr. J. A. Veatch, that boracic acid exists in the waters of the Pacific, from the Bay of San Francisco to the Cortez Shoals.* In the mineral kingdom, boracic acid may be found sparsely in tourmaline, and more plentifully in schorl—the latter being a common accompaniment of tin ores. It was in the examination of tin lodes and their accompanying schorlaceous contents that the writer was induced to infer that, like gold, tin has only been brought to the surface of the earth within a comparatively recent period, when measured in geological time. Boron, as boracic acid and borax, is extensively used in assaying, but is chiefly employed as an ingredient in forming the glaze of earthenware. Its use in both instances being as a flux, may it not be probable that it is still employed in a similar function in the profound molten depths below us, while silicon, as silica, and carbon in its various forms, were required at the surface in order to form the earthly cosmos as we now find it, forming additional proofs, if any were necessary, that "order is heaven's first law," however little that may be generally understood or appreciated.

Mr. Mallet deems earthquakes the consequence of aqueous vapor pent up under great tension in subterranean cavities; but how such highly heated aqueous vapor is to be formed, and volcanic energy displayed in any manner analogous to that exhibited by earthquakes, excepting upon the theory of a central heat, and that most likely a molten one, is difficult to conceive. Mr. Mallet also presupposes great cavities. That in limestone, great cavities are formed by the slow but continuous dissolving effect of water saturated with carbonic acid, is made evident in the most marked manner by the existence of the Mammoth Cave of Kentucky, the caves of Carniola, and others that could be adduced; but these would be insufficient to account for the phenomena of earthquakes. The only evidence that can be adduced in favor of the existence of such large internal cavities, as Mr. Mallet theorizes, will depend for support on the observations made during the Indian Trigonometrical Survey, in the course of which it was found from experiments made in the vicinity of the Himmalayas, from the results of which it has been concluded, by the surveyor, that the majority of these masses are hollow.

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*It is easy to diagnose how this may take place through the agency of steam acting upon schorlaceous minerals at profound and heated depths, and consequently under great pressure.

LIME, MORTAR, CEMENT, ETC

CHAPTER VI.

Hardening of Mortar; Climatic Conditions; Influence of Carbonic Acid on Hardening; Adhesive and Cohesive Qualities; Flexibility of Masonry and Brick-work; Tables.

> "By others' faults wise men correct their own."
>
> "Custom is the plague of wise men and the idol of fools."
>
> —Enfield's Select Sentences.

Lime, as is well known, when made into a paste with water, forms a somewhat plastic mass, which sets into a solid as it dries, but afterwards cracks and falls to pieces. Lime, consequently, does not possess sufficient cohesion to be used alone as mortar. To remedy this defect, and to prevent the shrinkage of the mass, the addition of sand is required. Sharp, quartzose river sand, is best adapted for this purpose. Books direct that the sand to the lime employed in making mortar should not be less than three measures of sand to one measure of lime, or more than four measures of the former to one of the latter. My own experience is, that if both materials are of the best quality, at least three and one-half measures of sand should be mixed with one of lime; and even a mixture of four measures of good Black Point sand mixed with one measure of well-burned Santa Cruz limestone, would make a much better cementing material than anything of the kind which I have seen used in the erection of stores and buildings in this city. I have used Black Point or North Beach sand for the purpose of illustration, because the sand at those places present the general qualities of that material likely to be continued in use for the purpose of making mortar in San Francisco. It is sand of a quality that may be termed fair for the purposes under consideration, but not first-class. When less than three and a half measures of sand to one of lime are used, the mortar so compounded does not set so well, nor so quickly, as with the proportions recommended. For building garden walls and masonry, or brick-work of a similar character, even one barrel of good lime, if well mixed with five barrels of the sand named, will afford, in most localities, a good enough cementing material for the purpose required in such instances. After the mortar has been *laid*, its subsequent hardening depends chiefly upon the thorough incorporation of the lime and sand during their mechanical intermixture.

This hardening of mortar is a somewhat obscure subject, and has never been sufficiently investigated in a scientific manner, though the writer believes, for reasons which will afterwards be adduced, that few subjects possess (unless masonry and brick-work are to be abandoned in the future erection and re-erection of stores and dwellings) a more economical interest to the residents of a city placed like San Francisco in a district which from time to time will be subjected to earthquake shocks. In a former chapter is republished a letter which was written by me on the earthquake of 1865, and published the same year, in the concluding part of which I intimated my intention of following it by a second one, for the purpose of making suggestions for palliating the evils arising from earthquakes. Finding, however, that all interest in the subject had passed away with the first fears caused by the shock of October, 1865, I never carried out the intention. After a careful examination of the damage done on that occasion, I then came to the conclusion that all the structures then injured, with very few exceptions, had their primary origin in defective mortar. The falling of the front of Popper's buildings was in consequence of a defectively supported and inartificial arch. The bricks displaced on the fire-walls of the same building could scarcely be chargeable as having been caused by using bad mortar, seeing that they had not been set more than a few days. Another marked exception I noted, to which the charge of bad mortar could not be fittingly applied, viz: the case of the entire front of a building, in the course of erection on Pacific street, which was thrown bodily into the street. In the latter case the bricklayers had only ceased working on the afternoon previous (Saturday), and the mortar had not time to set. A few cases also occurred where long and elevated fire-walls, not strengthened by any brace, were wholly or partially thrown down. All the other accidents on the occasion of the earthquake of 1865 may be traced absolutely to the circumstance of employing a bad material of mortar for building purposes. Similar remarks to those last made would apply, with pretty nearly equal justice, to the San Francisco earthquake of October, 1868. In the latter instance, however, no small share of the damage occasioned took place on, and was in a large measure caused by, the injured buildings having been built upon an artificial and imperfectly made foundation.

The simplicity of the operation of making ordinary lime mortar is such that the primitive method adopted thousands of years ago, has been continued over the lapse of the long intervening ages, without other change than the varieties in slacking, and the proportions of the ingredients to be mixed, just as the operator was desirous of obtaining a first rate or inferior article, accordingly as wisdom or ignorance or roughish parsimony, prevailed. Notwithstanding the antiquity of the process, and the long continued observation of the *hardening* of mortar in masonry and brickwork, on which quality its valuable property as a cementing material almost wholly resides, the theory of this *hardening* is very obscure and imperfectly, if at all, understood. The writer became more specially impressed with the last named fact in consequence of hearing it repeatedly remarked after the earthquake which occurred in October, 1868, in reply to observations made by him respecting the inferior character of the mortar employed for building purposes in San Francisco, that this inferiority arose from the mixture of impurities, such as decaying vegetable matter, salt, etc., in the sand employed in making the mortar used in this city; but the most observant and those most practically acquainted with the subject, such as architects, builders, etc., have in general arrived at the conclusion that some unknown climatic cause was the influencing agent in causing the solution of cohesion of mortar in this locality. My own views in the first instance were that overdosing mortar with sand, and aggravating the evil by using simultaneously a portion of hydraulic cement, accompanied by insufficient incorporation of the materials employed, were the chief influencing causes in occasioning that friable condition of mortar observable, after having been used only a few years for architectural purposes.

That climatic conditions should entail such deteriorating consequences as have been asserted by many, was, and still is, much doubted by the writer, yet a more careful study of the subject induces him to infer that these conditions may, and probably do, in more ways than one, injuriously affect the quality of lime mortar as a cementing material in our California climate,—a circumstance, however, greatly aggravated by the use of too large quantities of sand and mixing with hydraulic cement, in place of using pure lime, sand and water alone. It is well known that the induration of lime mortar is principally, indeed, for practical purposes, wholly induced by the absorption of carbonic acid,—in other words the reconversion of the lime of the mortar into its primitive condition of carbonate of lime, limestone, or chalk. This process of reconversion of the lime in mortar into a carbonate continues over a great length of time, especially in dry climates, and for the purposes of this inquiry the climate of California may be classed as amongst the dry ones. Well made lime mortar, after its application, becomes dry upon its surface, while at the same time it absorbs carbonic acid from the atmosphere; so far, however, as experimented on by the writer, with mortars from old castles erected from four to seven centuries ago, in various parts of Cumberland, Westmoreland, Lancashire, Yorkshire, Cheshire, and Staffordshire, a portion of the lime was always found in the caustic state or uncombined with carbonic acid, and Dr. Malcolmson found that mortar obtained from the Great Pyramid still contained a large portion of hydrate of lime.

A recent writer in the *Chemical News*, however, has stated that mortar obtained from Pevensey Castle, England, was not only free from any trace of hydrate of lime, but of silicate of lime also. I have quoted the last statement because such an occurrence is different from my own trials with mortar obtained from old castles in other situations, and also as being at variance with the results of all other experiments on this subject with which I am acquainted. This last circumstance is, however, one of very little economical importance to the matter at present under consideration.

If, on the contrary, fresh-made mortar is preserved from access of the atmosphere by any means,—such as being placed under ground, or being closely covered, especially if in considerable masses,—not only will its original properties be fully mantained, but its utility as a cementing material will be increased; the fact that old but well-preserved mortar was superior to that newly made, was a fact recognized and acted upon by the Romans, for, according to Pliny, Roman builders were forbidden by the law from using mortar less than three years old. At Vienna, I am informed, a law exists that mortar shall not be used until it is twelve months old. Of recent cases, commented upon by celebrated engineers, may be mentioned one which occurs in the writings of Smeaton, the engineer that designed and superintended the erection of the Eddystone Lighthouse. Smeaton had occasion to take up a large flat stone, of close grain, of about five feet square, that had probably not been moved for more than a century, having formed the bottom of a malt cistern, found on its removal that it had been bedded on a thick mass of mortar, which had become coagulated to a thick mass resembling cheese in consistence; but had never become perfectly dry, the original humidity having been so far retained that on being subsequently well beaten up without any addition of water, and afterwards allowed to dry, it speedily *set* to a stony hardness, the induration being much more rapid than what is observed with mortar as ordinarily made, and used soon after being mixed. One of the most remarkable instances of a similar character occurred at a German fortress, whose name I do not now remember, when in consequence of a siege, a large quantity of mortar, not being needed for present use, was covered up, and afterwards forgotten until subsequently discovered nearly two centuries after it had been made; the quality of the mortar so preserved was found on trial to be of the most superior quality. In employing old-made mortar, it should be kept in view that it ought to be well mixed, mechanically, before use, otherwise the major part of the benefits derivable from the employment of old, but not desicated mortar, will not ensue. There can be no doubt that the extra mechanical mixing required by long made hydrated mortar forms a most important feature in promoting its utility. As an illustration of this point it may be mentioned that it has long been known that grout, which only differs from ordinary mortar in consequence of its being made more liquid, owing to a more liberal use of water, is frequently found to *set* with difficulty; if, however, previously to being used, such grout is long and thoroughly beaten and mixed, it will be found, on application, to harden much more rapidly by such beating, often being found susceptible of hardening in the course of four-and-twenty hours.

There exists no doubt in the mind of the writer that one of the causes for the superiority of mortar that has been long made is found to be in the fact that the lime employed becomes more thoroughly hydrated, as it is well known that the ordinary plastering of walls occasionally *blisters*, in consequence of deficient hydration of the lime composing the plaster, when the latter has only been recently prepared.

Although the last named fact is by no means an unimportant one, it will not suffice for the great advantage found to be derived from the use of mortar that has long been mixed, the chief cause of the beneficial effects derivable from employing mortar that has been long made must be sought for elsewhere. To the writer it occurs that the great difference which takes place in the time required for hardening, and the full development of the cohesive and adhesive properties, of newly and long-made mortars, arises from the fact that in new-made mortar the hydrate of lime exists in an amorphous, while in old-made mortar the lime, either wholly or partially, changes the amorphous hydrate into the crystalline condition, the latter being one more probably calculated not only to retain moisture but also to absorb more readily carbonic acid from the atmosphere, its molecular condition at the same time being more susceptible of conversion into a crystalline carbonate, by the absorption of the gas named. If future experiments should demonstrate the opinion just given as being based on correct views, it would be easy to point out modes by which the same end could be attained without waiting the slow influence exercised by time, however sure and beneficial that influence may be. Incidental notice may here be taken of a proposition which has recently been announced, viz: the economy and general advantage that would be derived by lime dealers becoming mortar manufacturers. If our city, in its future extension, was likely to be confined to the water-front, and the narrow breadth of alluvium, mud-flats and water lots, which lie at the foot of the sand-hills which encompass on the west this narrow strip of alluvial soil, no fault on the ground of economy could be advanced against the proposition. No disadvantage in such a case would follow from hauling sand, whether as sand or mortar, to the greater part of the ground named, or hereafter to be artificially made, but the bulk of our city that will have to be built in future lies immediately contiguous to, and amongst the sand-hills, from which can be derived on the spot where it would have to be consumed, illimitable quantity of the most bulky and heavy material required for making mortar. The cost of hauling five tons of sand and water, accompanied by one ton of lime, from Black Point to the Mission Creek, at which latter place sand and water can be obtained in abundance, would be absurd, and would cost much more than any benefits that can be anticipated from purchasing mortar ready mixed in place of buying the materials required.

From the function which carbonic acid plays in the hardening of mortar, the consideration of its properties is intimately allied with the development of its full adhesive and cohesive powers. This gas is absorbed in volume by water, to a trifle more than its own bulk, at the ordinary temperature and pressure of the atmosphere, being proportionately less, with the increase of the former and decrease of the latter, the proportion absorbed by vapor of water is probably *cæteris paribus* in like proportion. In England, which may be said to possess a moist climate, it has been ascertained that its atmosphere contained in 100 volumes, 1.40 of aqueous vapor, and .04 of carbonic acid. Yet from such a small proportion of carbonic acid existing in the atmosphere, all the lime mortar which we employ for building purposes has to become indurated by its absorption,—an absorption which will be accelerated or retarded in proportion to the moisture present in the mortar employed, or in the atmosphere. If moisture is retained by mortar, from that cause alone it will be more susceptible of absorbing carbonic acid from the atmosphere. If the atmosphere happens to be saturated with aqueous vapor, it will yield carbonic acid to newly-laid mortar in greater quantity If, however, the atmosphere happens to be a dry one, as that of California is during the Summer months, the tendency will be for the atmosphere to withdraw moisture from fresh-laid mortar, and thus impair its power of absorbing carbonic acid, while at the same time it is highly probable that in such a desiccated state of the atmosphere a less volume of carbonic acid exists therein than when the same is more saturated with aqueous vapor. It is from the causes just assigned that it has been observed that the mortar employed in building in San Francisco hardens more rapidly in the winter than in the summer season.

As if to render these unfavorable conditions still more injurious, hydraulic cement is habitually mixed, in San Francisco, with lime mortar. Such a step undoubtedly aids the more immediate hardening of the mortar so made, but it is at the expense of the future adhesive and cohesive properties which it would attain in the course of time, by the slow absorption of carbonic acid.

THE ADHESIVE AND COHESIVE QUALITIES OF MORTARS, AND THE FLEXIBILITY OF MASONRY AND BRICK-WORK.—The *ad*hesion of mortars and cements to stone or brick in a direction perpendicular to the faces of the joints of the work, is always much less, with ordinary materials, than the *co*hesion of the latter for equal sections; it therefore almost invariably happens that the lines of fracture in walls after earthquakes, whether in stone-work or brick-work, composed of good bricks, follows down or along a line of joints, producing a jagged or serrated fissure, the jaws or serrations depending upon the length of the bed of each block or brick, and the depth of the courses.

It has been found that the adhesion of Portland cement to Portland stone is 146 pounds per square inch, while the cohesion of the cement itself is 400 pounds ditto; and that of Parker cement to granite, 22 pounds, the cohesion of the cement being 300 pounds ditto.

The adhesion of common lime mortar varies enormously with the nature of its materials, the sort of stone or brick with which it is used as a cement, the thickness of the joints, the care taken to fill them effectually and solidly, the degree of wetness or dryness of the mortar itself, and of the stone or brick to which it is applied, the rate at which the mortar has been dried during its setting, and the amount of moisture and air to which it may have been subsequently exposed. All these conditions, or some of them, have been found sufficient to make a difference of absolute cohesion of more than 2.1, between old

Roman mortar, consolidated and hardened for ages, and good modern mortar, allowed sufficient time to be viewed as fully set or indurated. In many cases, very dry mortar has been found much more brittle and easily fractured than when wet, even after complete induration has occurred.

The actual extent of elastic flexibility of stone and brick masonry, especially the former, is not commonly considerable; and unfortunately as yet no *precise* measures of these exist for any class of masonry. Were it not for this property, however, no building would stand even a moderate shock; and were the velocity of the wave confined within the limits of the velocity of the center of oscillation of the structure, considered as an elastic compound pendulum, whose time of vibration is due to the length of a simple pendulum equal to the hight of that center above the base, and were the amplitude of the shock within the limit of elastic displacement of the masonry, etc., at that center, no building would be thrown down.

A well constructed brick and mortar wall of thirty or forty years' induration and 40 feet in hight, unsupported, two bricks or 1.60 feet* in thickness, has been observed by Mr. Mallet, to vibrate nearly two feet transversely at the top, during a storm of wind, before it fell; and that not until after many oscillations had disintegrated some of the horizontal joints, and produced several vertical fractures.

The point of greatest flexion traversed along the length of the wall, as each oblique gust of wind impinged upon it, like the waves of a rope suspended at one end, and jerked transversely at the other.

An octagonal brick chimney stack, with a heavy granite capping 160 feet in hight above the ground, was instrumentally observed by Mr. Mallet to vibrate in a moderate gale of wind, when a few months built, nearly five inches at the top.

The above are illustrative of the extent of flexibility in good brick-work, which possesses that property in a far higher degree than other masonry; the bond of the mortar being better, the flexibility being greater, both in brick and thick mortar joints,—the latter being very numerous and the elasticity more nearly alike in both, than in stone masonry. When the joints are much fewer in proportion, the stone, relatively to the mortar, highly elastic and rigid, and the bond, so far as adhesion of the mortar is concerned, small, (in the case of many hard silicious stones, such as granite, almost *nil*) the result of this difference is, that well-built and indurated brick walls, when fractured, breaks

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*The English brick is 9x4½x3 inches.

indifferently, nearly through joints and bricks; but in stone walls the line of fracture is confined to the mortar joints, with rare exceptions the rigidity of the several blocks transferring the whole of the compressions and extensions due to the strains, to the mortar above. From this cause it was observed very uniformly throughout the earthquake region, that when a brick construction was superimposed upon stone-work, as is seen in Italian churches, the brick-work, although of so much less density, fell as one mass, with fractures of severance along the lines of junction of the two; and *vice versa* when the brick-work, as in a few cases, was beneath, and stone-work above; and when the latter was thrown, it did not push the brick-work over in its fall,—the latter remained comparatively unharmed.

The limit of flexibility of stone masonry exposed to earthquake shocks depends, to an immense extent, upon the flatness and superficial area of the beds of the individual stones, and the completeness with which "breaking joint" and thorough bonding are preserved in the setting.

Where the masonry consisted of rounded, lumpy, quadrated ovoids, of soft limestone, as already mentioned in the general description of the poorer and older towns (such as Polla), the whole dislocation occurred through the enormously thick, ill-filled mortar joints; and almost all buildings thus formed fell together at the first movement in undistinguishable ruin. At Pertosa, a poor but more modern town, the class of masonry was a little better, and, it may be remarked, the ruin less complete.

When, as in a few examples observed, the masonry was of the best class (and such as would be so recognized in England), the buildings thus constructed stood absolutely uninjured in the midst of chaotic ruin.

As a striking illustration of the exception just alluded to, Mr. Mallet draws particular attention to the Campanile of Atena—a square tower, of about ninety feet in hight and twenty-two feet square at the base—in which there was not even a fissure, while all around was nearly prostrate. This tower was also aided by iron chain bars, built in at each story. The great viaduct carrying the military road at Campostrina is adduced by the writer as another example of like character. He appends, also, the following remarks, which, owing to the strong parallel case which may be drawn between the effects of the great Neapolitan earthquake of 1857 and that of the 21st of October, 1868, at San Francisco, I now insert in small capitals:

"Indeed, it was evident that had the towns generally been substantially and well built, or, rather, the materi-

ALS SCIENTIFICALLY PUT TOGETHER, VERY FEW BUILDINGS WOULD HAVE BEEN ACTUALLY SHAKEN DOWN, EVEN IN THOSE LOCALITIES WHERE THE SHOCKS WERE MOST VIOLENT AND THEIR DIRECTION THE MOST DESTRUCTIVE. THUS THE FRIGHTFUL LOSS OF LIFE AND LIMB WAS AS MUCH TO BE ATTRIBUTED TO THE IGNORANCE AND IMPERFECTION DISPLAYED IN THE DOMESTIC ARCHITECTURE OF THE PEOPLE AS TO THE UNHAPPY NATURAL CONDITION OF THEIR COUNTRY, AS RESPECTS EARTHQUAKES."

The following tables will be found of great practical interest to the architect and builder:

RESISTANCE OF MATERIAL TO PRESSURE AND TENSION.

MATERIAL.	Weight in pounds per cubic foot—Sp. gr.........	Pounds per square inch; resistance to pressure.....	Pounds per square inch; resistance to tension......	Authority for Nos. 1 and 2...	Authority for No. 3............
Hard Brick........	98	1851	206	Rondelet.	Gauthy (sur la construction des Ponb) and Rondelet (L'Art de Bater).
Soft, ill-burned brick............	91	1200	133	"	
Mortar, lime and sand, unground.	102	423	47	"	
Mortar, lime and sand, ground...	109	577	64	"	
Mortar Pozzolano, of Rome and Naples, unground	92	503	56	"	
Mortar Pozzolano, of Rome and Naples, ground...............	105	732	81	"	
Mortar, old Roman (Campagna).	97	1047	105	"	
Mortar, old French Bastile......	94	753	84	"	
Plaster of Paris (mean)........	....	500	55	Laisne.	

The few experiments made on the subject tend to show that the resistance of stones, etc., to tension, varies from one-eighth to one-tenth the resistance of the same material to compression. The third column, so far as bricks are concerned, was calculated at the mean of these data.

ADHERENT RESISTANCE OF MATERIAL.

MATERIAL.	Weight per cubic foot—sp. gr....	Resistance to Tension—Lbs. per square inch....	Adherent Resistance—Lbs. per square inch....	AUTHORITY.
Granite to Portland Cement.....	164	....	97	Tredgold.
Granite to Parker's Cement.....	164	....	22	White Trans.
Kentish Rag and Parker's do....	.. ..	....	29	do.
Oolite and Parker's Cement.....	....	....	42	do.
Oolite to Portland Cement......	....	....	146	do.
Mortar (sand, 3; lime, 1)...... ..	100 to 119	11 to 20	9.88	Boisted and Gauthey.
Mortar, green and fresh...... ..	....	2	....	Treuissard & Totten.
Mortar, ground lime and tiles. / Hydraulic Mortar....	100 to 120	40 to 80	5.26	Boisted, Gauthey, Treuissard and Totten.
Jurassic Limestone to Mortar. ..	....	....	3.80	Rondelet.
Brick and Tile to Mortar........	....	....	8.27	do.

In the above table, the cements had, in all cases, six months to indurate, and the mortars (except in the second case) from six to seventeen months' induration.

PALLIATIVES.

SUGGESTIONS AND CONCLUSIONS.

CHAPTER VII.

The Physical Character of the Bay and the Country Surrounding San Francisco Calculated to Protect that City from any Earthquake, Ocean-Wave, or Serious Land-Slips; Preservation of Timber.

> "The cloud-cap't towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> Yea, all that it inherits, shall dissolve,
> And, like the baseless fabric of a vision,
> Leave not a wreck behind."—[TEMPEST.

Before this chapter had been reached, the printer had warned the writer that more copy was then in hand than would complete the work as originally contracted for. The consequence has been that much that had been written, especially respecting lime and cements, had to be withdrawn, and all on the geology of the district and its bearing on the character of earthquake shocks, as well as the local facilities for furnishing suitable materials for building, as stone of various kinds, together with the origin and character of the clays in this vicinity, their adaptability for making bricks, with suggestions for the better and more appropriate manufacture of the latter—for the same reason—has to be omitted. When thus warned I had not commenced treating on the adaptability of different kinds, and preservation of timber, for structural and other economical purposes, which, although one of notable importance, this branch of the subject does not force itself on the attention as being so intensely pressing as the different subjects more immediately allied to present structural safety. Something on the last named topic has been alluded to in the preface. For the reasons more than once named, I feel myself excluded from making use of much valuable information, given to me by my former co-secretary, Mr. M. Bridge, respecting the character of the soil forming the foundations of a large part of the city, as well as many noteworthy suggestions, having resolved to confine myself, as far as possible, for examples of principles, to such as are of world-wide and general application. I regret having to omit much that I had written respecting the "earthquake echo," particularly as a gentleman residing at Oakland furnished me with what, according to his description, appears to have resulted from a well-marked instance of this theorized characteristic of earthquakes. A long time, however, cannot elapse before I anticipate being at full liberty to make use of all the knowledge which I may consider useful and pertinent to the subject, which I have collected or may yet ascertain, respecting the San Francisco earthquake of October 21st, 1868.

Truth compels the admission that a portion of California, including the locality around San Francisco, is, at indefinite periods, subjected to the action of earthquakes. It fortunately so happens that the physical geography around this city is of such a character as to largely modify, if not wholly obviate, many of the dangers which are found sometimes to occur when earthquakes take place at or near the seaboard. Allusion is here more particularly made to ocean earthquake-waves and landslips. The first is not found generally destructive, excepting in the cases of harbors immediately open to the ocean or near the *debouchure* of bell-mouthed rivers or bays. Landlocked as the harbor of San Francisco is, even if an earthquake ocean-wave sixty feet in hight was to break on our outlying western shore, it could only penetrate into our harbor by the width of the narrow passage of the Golden Gate, which, as it rapidly expands after its entrance, to the north, south and east, within a short distance from the narrowest part, and would have to travel some miles before its effects could be felt at San Francisco, ere its arrival at which point its force would be much modified by the resistance it would have received, by the various rocks and islands which it would have to pass in the course of its progress.

The other danger that we are not likely to encounter to any ruinous extent, is that which might probably arise from landslips, notwithstanding the extension of the city front into the bay, from time to time, through the interested influence of speculating land-grabbers, with former legislatures; as much as possible, has been accomplished to bring about so undesirable events as landslips. Owing to the fact that our bay is comparatively a shallow one, we are not likely to witness a newly and solidly constructed wharf, as in the case of the earthquake at Lisbon, destroyed and replaced by deep water, in consequence of a landslip. Though partial fissuring amongst the unstable ground of our water lots may take place, and irregular shrinking and elevation of foundations so situated, may occur; sufficiently so as to be calculated seriously to damage massive and elevated brick or stone structures which may be erected on such *made* and generally unconsolidated ground, but a serious landslip need not be apprehended.

In fact, as is well known to its residents, the damage caused by earthquakes at San Francisco and around its bay, almost wholly took place on alluvial soil, or made ground, as at Lisbon, the South American cities, and many other places; the next greatest amount of damage having occurred where buildings had been erected on foundations most nearly allied in characteristics to those just noticed. Notwithstanding the explanations given and the opinion expressed by Mr. Mallet, I am inclined to believe that greater danger *does* exist to dwellings placed upon deep, alluvial soil than when erected upon a rocky foundation. Exceptional cases may occur, and doubtless have occurred, but such exceptions, I suspect, will go to prove the general correctness of the opinion which I have expressed.

With Mr. Mallet I believe that the greater danger to erections placed on alluvium arises from the amplitude of the wave being greater in such strata than when passing through solid rock. It is a noteworthy fact that although the great earthquake waves which accompanied the South American earthquakes of last year, and also the previous one at the Sandwich Islands, which accompanied the last great volcanic outbreak in that locality, were most distinctly indicated by the self-registering tide gauges at San Diego and Fort Point, while not the slightest oscillation was noted for the California earthquakes of Octobers, 1865 and 1868,—a pretty satisfactory indication, coupled with the fact that the shocks on those occasions were scarcely felt at the south and east of the Bay of Monterey, that the focus of these earthquakes must have existed somewhere between San Francisco and the bay named. Indications exist, also, that the focus must have laid between the Pacific Ocean on the west and the San Joaquin Valley on the east, on the occasions named.

Sufficient has been stated in the previous chapter to make it readily comprehensible to ordinary minds in what consists the mechanical character and effects of an earthquake; with the dissipation of the mystery which has so long enshrouded this subject, owing to the frequent anomalies which have been observed to accompany this phenomena, and formerly unaccounted for, much of the alarm which earthquakes are calculated to excite will disappear also, at least from all reasonable minds, especially if proper precautions are taken to erect our structures in future, and to adapt those already existing, to meet those telluric phenomena in the several forms in which we may anticipate their occurrence. There can be no doubt that earthquakes *may* occur, such as those at Riobamba and Jamaica, when Port Royal was destroyed, owing to the force and steep emergence of the shocks which took place at those places, from the effects of which no human structure could be erected capable of withstanding unscathed their disrupting influence. Such cases, however, occur very sparsely, as sub-ærial phenomena, but there does exist the strongest reasons for believing that by far the most tremendous earthquakes that have occurred, to the effects of which only, can the geologist point out some of the chief phenomena connected with that branch of his science which is connected with upheaval, have been sub-aqueous, and if space permitted, it could easily be shown that earthquakes, most probably, are far more numerously of sub-aqueous than of sub-ærial origin, after making all proportional allowances for the difference of surface occupied by water and land.

Although the subject of palliatives to the destructive consequences which may occur to buildings in consequence of earthquakes, was one which the writer originally proposed to have dwelled upon at some length, it never was contemplated by him to enter into much details, deeming such as belonging more particularly to the architect. The lessons derived from earthquakes, relative to the erection of buildings, whose exteriors are to be composed of materials almost wholly obtainable from the mineral kingdom, are that these materials should, when used for this purpose, possess as much homogeneity as possible, with a certain amount of flexibility. Rigidity in a wall and its almost constantly corresponding accompaniments,—hardness and sonorousness,—being favorable to the transmission of the shock upwards, and so calculated to throw off the uppermost series, especially if such happen to be ornamental work, unattached excepting at the base. It can scarcely be doubted that it was from this cause that at the earthquake in San Francisco, October, 1868, several instances took place of such ornamental stone-work being thrown from their positions, when surmounting buildings entirely constructed of stone and cemented with the best mortar, yet in their immediate vicinity, ornaments on brick buildings remained undisturbed, notwithstanding they had not been so well cemented into their places, and at the same time possessing forms and magnitudes better calculated to promote their overthrow. It would therefore be decidedly erroneous to select materials for building merely on account of the qualities relating to rigidity and strength, for under the rapidly dynamic influence of an earthquake shock, rigidity may easily fracture where flexibility would be uninjured.

In wood we have a flexible material, and it has been proposed to remedy the inflexibility of stone, and brick-work, by the introduction of timber-studs and tie-beams into walls. Buildings, so erected, if they did not give way partially or wholly at the first heavy earthquake shock, would, in a short course of years, be likely to become very much racked in an earthquake country by the repetition of small ones, as a consequence of the incongruous character of the associated material,—a marked instance may be noticed, by referring to the San Leandro Court House, on the occasion of the earthquake of 1868. After carefully weighing all the circumstances that are associated with the employment of mineral substances or timber, alone or in combination, for the construction of exterior or interior walls, the balance of evidence appears to be in favor of using these substances alone for those purposes; their difference of elasticity and limits of fracture being so very great. The modulus of elasticity of brick-work might however be considerably increased by making bricks somewhat thinner, say only two inches in place of two and a half inches in thickness, this combined with the fact that such diminished thickness of brick would be accompanied by a proportionate increase in the amount of mortar used, would conduce to a much greater homogeneousness of structure, provided the English bond,* according to the strict meaning of the term, is invariably employed, that, viz: every course of stretchers is always immediately overlaid by a course of headers, and this rule ought to be enforced under severe penalties, the non-attention thereto, accompanied by the use of bad mortar, have been the sole causes of the destruction of life and chiefly of the destruction of property occasioned in this city by the earthquake of the 21st October, 1868.

A few words may be said respecting the most desirable size of bricks to be employed in the future construction of buildings. The Roman brick is described as having been seventeen inches in length by eleven in width; thickness I have not seen stated, inferring, however, from specimens which I have seen of Roman brick-work at the Flint Lead and Alkali Works, occupied by me before they were purchased by the present owners, Messrs. Muspratt & Co., I am induced to believe that they were comparatively thin, for those which I am acquainted with, found *in situ* as above stated, did not probably exceed more than one and a half, or at the outside, one and three-quarters inches in thickness. They were not, however, either so long nor so wide as the example first cited. A convenient size, in my opinion, would be 12x6x2 inches.

* As far as I can learn from builders the term Flemish bond, is employed in San Francisco for a mere modification of English bond.

Such a form, I believe, would add greatly to the limits of the elasticity of a wall erected therewith, as compared with another composed of ordinarily sized bricks, and if the upper stories or story of a very elevated building was constructed of hollow bricks,* and all well bound together by the very best made *lime* mortar. I have no doubt that buildings formed of walls so constructed, if erected on a solid foundation, would withstand earthquake shocks equal to those which in part destroyed Lisbon on the 1st of November, 1755, and desolated such a large number of cities in the kingdom of Naples on the 16th of December, 1857, or the South American ones which occurred during the fall of last year.

Respecting wooden or frame buildings, notwithstanding no actual danger may be apprehended by the sole use of timber, in the construction of elevated dwellings, such as those of four stories elevation, it is by no means advisable that dwellings so constructed should exceed two stories in hight, the great flexibility of the material making it more susceptible to the effects of the earthquake shock, as compared with those of bricks. If it happens on such occurrences, that any inmates should be occupying the upper stories, the swaying motion may become alarming, though not actually dangerous; to females in particular, such feelings of alarm are particularly likely to prevail with considerable force. In fact, I am perfectly well acquainted with the case of a lady who was months before she recovered from the effects of the shock of the 21st of October, 1868, in consequence of the sensations occasioned by a motion such as described, which occurred in the fourth story of a dwelling situate in the higher part of Post street. I may state that the lady is not by any means possessed of a timid disposition. As one of those apparent anomalies of earthquakes, it may be mentioned that the husband of the lady alluded to was at the same time taking a stroll amongst the bushes on the contiguous sand-hills, and felt the shock so slightly that he was not aware that an earthquake had occurred until his return home.

There can be no doubt, however, that had a dwelling of similar character been erected on the sand-hills alluded to, the swaying motion would have been equally great, provided the stratum below the sand-hills was of a similar lithological character. It is such apparent dis-

*The advantages of using hollow bricks for the upper parts of high buildings can only be slightly referred to. One of the chief advantages obtained by their employment, consists in their greatly reducing top-weight. It is by no means improbable that the thinness of Roman bricks was the result of observing the better adaptability for resisting earthquake shocks. The chief opposition to the use of bricks of the size which I have named above, will most probably come from the workmen, as they will be not quite so readily grasped as one of four inches width.

crepancies that have lent so much aid to the dissemination of the magnetic and electric theories of the origin of earthquakes.

Power of ornamentation will undoubtedly possess a powerful influence in deciding what shall be the species of domestic architecture hereafter to be adopted generally throughout the State. In this respect wood possesses great advantages over dwellings whose walls are composed of brick or stone ; the adaptability of wood for gilding and exterior polychromic adornment is illimitable, and peculiarly so with a great variety of Asiatic architectural styles. Many of these are peculiarly suitable for rural dwellings, whether it relates to the erection of a simple cottage or one of palatial proportions. The styles alluded to embrace all the varieties that dome-shaped structures are capable of assuming, either with or without the accessories of towers and minarets ; glass and iron, combined with wood, as materials, are peculiarly well adapted for the kinds of architecture noticed, and for accompanying floral and subordinate arboral ornamentation, none excel them. Fountains in many cases could be brought in aid to highten exterior and interior effects, while the waters might by easy contrivances be made economically available for irrigating purposes. Such are some, and only some, of the amenities which may be made to pertain to rural wooden structures by the judicious employment of coloring, gilding and varnish. For interiors, in place of plaster, less pretentious dwellings may be made secure, comfortable and ornamental, by due attention to the graining of the timber employed in interior linings, especially as many varieties are susceptible of tints agreeable to the eye, while those of a more extended and expensive description possess, in *papier-mache* and *carton-pierre*, a plastic material of almost limitless application for the purposes of wall and ceiling decoration. It may seem Utopian to some to here make allusion to substances whose useful applications are at present so little known in this community ; but if this State is at all to equal the aspirations expressed by many, as a textile producing country (and few can appreciate its capabilities in this respect in a higher degree than the writer), we shall in a short period possess in the waste materials of such crops a practically illimitable source of the raw material required for making the useful and decorative articles alluded to ; one of the chief utilities of which would be found to consist in the circumstance, that owing to their greater elastic limits, as compared with lime plaster, they would not injure by cracking, either from natural atmospheric causes or the effects of earthquake shocks.

A draw-back to the advantages above set forth of using wood for architectural designs exists in its inflammable character, to which may also be added its general liability to decadence. I shall allude to these two drawbacks as one, because both are preventable and can be attained by the same means at one operation. If, however, these valuable results are to be made practically and economically available, it will be requisite that the substances to be employed for the purposes proposed shall be attainable like the sources of raw material for making *papier-mache*, those generally consumed by the paper manufacturer, or the agriculturist for manure, viz: the employment of substances valueless for any other purpose than some particular specialty. We possess, in this city, about half a dozen modes and proposals of modes, for preserving timber, but the substance or substances employed for this purpose cost in the average from two to two and a half cents per pound. In order to be sufficiently economical to thoroughly impregnate timber with any of the substances so proposed to be employed, these chemicals ought not to cost much more than the charges of hauling and the requisite manual labor required in handling.

We ought to be under no necessity of importing these substances, for in California we have a limitless field for their cheap production, as will become evident whenever a rational system of metallurgy is adopted by those interested in the reduction of our auriferous and argentiferous ores; space, and time also, now forbid entering into any lengthy details on this branch of the subject. If sufficient attention is given to the present treatise by the amount of patronage accorded, I shall probably be induced to present an extra sheet relating to these matters at an early day.*

On the use of iron in strengthening wooden, stone and brick buildings, I shall omit making notice from want of space at my disposal. I the more regret this circumstance, as I see that metal in many cases most inappropriately applied for the purposes intended. If, however, what is now given to the public meets with its approbation, it will be easy for me, in a second part, to give *in extenso* my views on this and many other subjects, which are either wholly omitted or only partially touched upon.

The delay so occasioned by the omission at the present time of the matters noted will probably prove advantageous to the future rational discussion of those which are omitted, for in order to do this it is indispensably requisite that we should in the first place fully comprehend what an earthquake is, and consequently its origin. It has been one of the chief aims of the writer to impress his readers as far as in his power

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*The loss in bullion suffered by this community during the last ten year from unskillfulness does not fall short of $70,000,000, nearly all of which amount might have been saved, not by some new *process*, as such is called, but by the rational application of methods long known, which could be readily and economically applied under able management.

lies, with what he considers to be the true *vera causa.* When this is well understood and acquiesced in, the appropriate construction of buildings to resist earthquake shocks becomes comparatively easy. An increased length and diminished thickness of brick, as previously noticed, would, I think, when laid in good lime mortar, mixed in the proportions named, accomplish all that is needed for safety, so far as security may depend upon the character of the materials employed in the construction of interior and exterior brick walls. The *bond* is the next matter of importance, and that should be either the genuine English or Flemish, with bricks of the form of 8x4x2½ inches; the English will be found the best. If, however, bricks were made 12x4x2, as suggested to me by an architect of this city, instead of six inches wide, as named by me in a former page, perhaps the Flemish bond might be found to possess some advantages ; under any circumstances, if a law does not now exist, one ought to be obtained as early as possible, prohibiting, under the severest penalties, the erection of brick walls unless the bond alternated every other course, one of which should be the compulsory re-erection of any portion of a wall in which a layer of stretchers was not overlaid by a layer of headers. It has frequently been noticed by architects that corbels should be used for the support of joists and timbers. These possess many advantages. Such a mode, however, presents some that are not so, when we come to examine into the conditions which may occur with earthquakes.

When properly explained and fully understood, the earthquake becomes far less mysterious than thunder and lightning, and with the dissipation of the mystery hitherto accorded to its dynamic origin,* much of the alarm arising from its occurrence, it is hoped, will cease to trouble timid minds. Timidity has certainly been carried to excess by those who have left or expressed a purpose of leaving this State on account of earthquakes. To such the question may be asked, where would they go to avoid earthquakes? To Massachusetts? Why, Boston was shaken to its very center by an earthquake in 1755. To Missouri and the Valley of the Mississippi? This large section of the United States was agitated by earthquakes for months during the year 1812. To England? When Shakspeare wrote the splendidly poetical description of earthquakes in which he so graphically states,

> "Shakes the old beldame Earth, and topples down
> High tow'rs and moss-grown steeples."

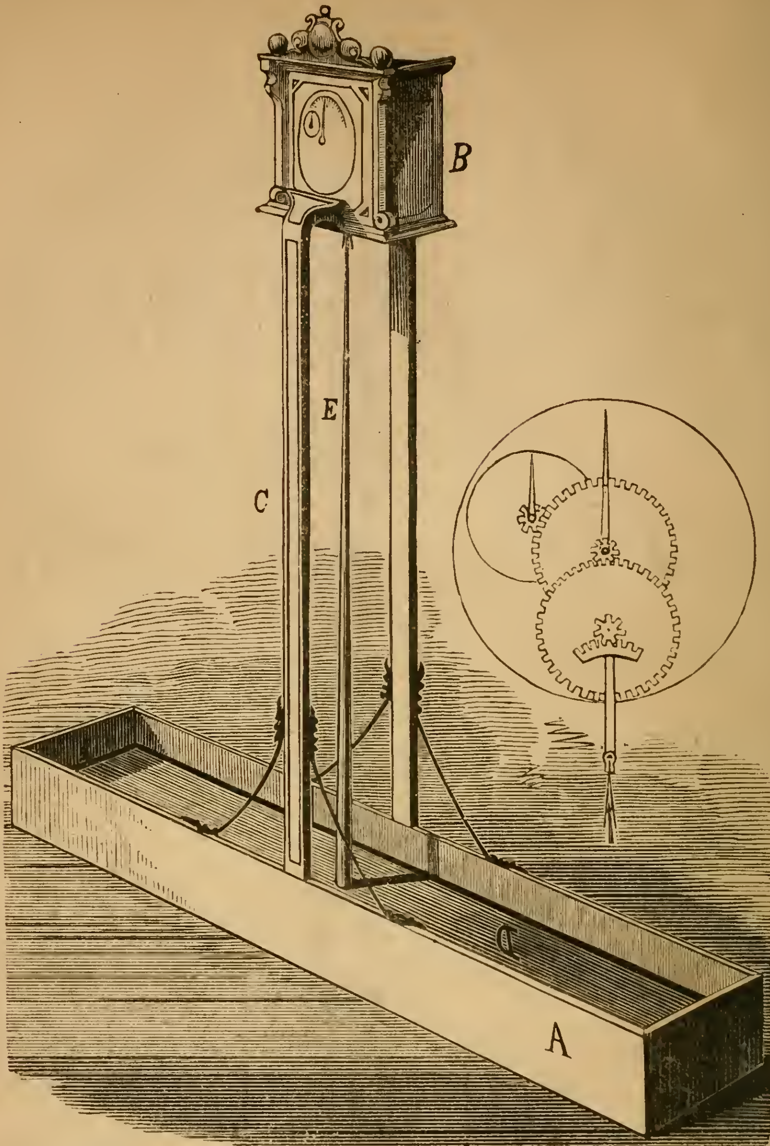
*With the exception of the magnetic and electric theory of the origin of earthquakes, all others agree as to a common dynamic force which originates earthquakes. There may be disputes as to how that force originates, but that will make no difference in the character of the nature of the precautions which ought to be adopted to alleviate or obviate its disastrous effects.

These sentiments were written by the bard of Avon under the inspiration of the traditional accounts handed down to his time, of a severe earthquake that took place in England about a century previous, at which period several churches in that kingdom had been leveled, and cathedrals damaged by one of these phenomena. Where, then, shall the timid flee in order to avoid earthquakes?

It is well observed by Mr. Mallet, that "all human difficulties to be dealt with must be understood. Were understanding and skill applied to the future construction of houses and cities in Southern Italy, few, if any human lives, need ever be again lost by earthquakes, which there must recur in their times and seasons." Mr. Mallet states that this important fact has been pointed out by several Italian writers, and that Colosimo, in a brief account of the Calabrian shock of 1832, has described some of the conditions that should be observed in the erection of buildings. Read California for Southern Italy, and the remark will apply with equal, if not greater force.

NOTE.—On revising the last sheet, it was discovered that in withdrawing much that had been written respecting the magnetism and electric source of earthquakes, all notice of the labors in this field of Mr. W. F. Stewart, of San Jose, had been omitted. I regret the circumstance, as Mr. Stewart's accumulation of facts on this point possess an undoubted value; and it is to be hoped that they will appear at a not distant day in book-form. I have great pleasure in adding, that although differing in opinion, the most friendly feeling exists between Mr. Stewart, Mr. Rhodes and myself—truth only being the aim of each. If we differ, "we agree to differ."

Circumstances have also compelled the omission of a full description of the drawing which appears on the last page of the cover of this work, of an instrument invented by one of our practical workers and intelligent thinkers, Mr. Herring, of Forbestown. This instrument is more specially intended to indicate minute oscillations of the earth for the purpose of correcting astronomical observations; but Mr. Herring thinks, and it is quite probable, that a record of the minute secular changes which have been proved to have taken place on ground supposed to be the most fixed,—Greenwich and Armagh Observatories, for instance,—may be useful as affording occasional warnings of approaching earthquakes. The engraving of the instrument will appear in the *Mining and Scientific Press* on May 15th, 1869, with a more complete description and explanation.



EARTH MOVEMENT INDICATOR.

It has been discovered that the Earth's surface is sometimes subject to moderate local movement not perceptible through any of the ordinary modes of observation. It is possible that these unobserved movements are most decided and prevalent in earthquake times, and places. With this view, Mr. F. A. Herring, of Forbestown, Cal., has invented the device mentioned on page 96 of this work, and briefly described as follows: The box, A, is to represent a large reservoir, partly filled with water, and designed to be placed at sufficient depth in the ground to secure even temperature. O, is a wooden float covering the surface of the water. The slightest oscillatory motion of the earth will change the surface of the water and produce motion of the float and the standard E, whereby action will be imparted from the point of the standard to a system of gearing in the case B, moving the indicator shown on the face of the dial. On the right of the engraving will be seen an enlarged view of the gears, showing the segment which actuates the system through the movement of the depending lever in which the point of the standard E is inserted. Thus, on the slightest oscillation of the float, the point of the standard E will be many times multiplied and minutely indicated by the pointer on the dial-plate.